ary Maps Explained

EAMES

MILITARY MAPS EXPLAINED

BY

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PREFACE.

The increased use of maps in our Service, both in map problems, map maneuvers (War Game, or Kriegsspiel), and in the annual maneuvers in Federal and State camps of instruction, would in itself increase the importance to officers and non-commissioned officers of the subject of map-reading, but the true importance goes beyond this in that a proper preparation for war presumes a knowledge of this subject on the part of all officers. Modern war is largely fought on maps, and the Art of War is, to a large extent, taught in time of peace by means of situations assumed in connection with maps. Many officers have never given this study the amount of attention that it deserves, and many others have forgotten the instruction they received in it at the U. S. Military Academy, and it is in the hope of assisting both classes to ac-

quire the necessary facility in map-reading that the following pages were written.

The explanations are made as simple and as practical as possible, so that one may take up the study from this text without previous preparation, but the subject is completely covered, and one who has mastered the principles here laid down, be he Regular, Militia, or Volunteer, will be prepared to solve all the problems in connection with map-reading that the fortunes of war—or of peace—may impose upon him.

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Fort Leavenworth, March, 1908.

MAP-READING.

I.

The Use of Maps in War.

Hand in hand with the development of the science of war has advanced the science of Topography; and as war emerged from the domain of art into the cold, true atmosphere of science, soldiers have placed more and more reliance upon the cartographer's representation of the theater of operations.

Up to the beginning of the seventeenth century, maps were either purely geographic or were geographic maps on which attempts were made to show hill features and other topographical incidents by pictorial effects, rather than by the exact methods of to-day.

During the seventeenth and eighteenth centuries attempts were made from time to time to

represent the topography of the country on a more scientific system, which had for its basis the use of contours instead of the usual perspective projection of hill-features. The proper use of a contoured map, however, required a higher degree of training in map-reading than was generally possessed at that date, and a compromise was struck, which resulted in a sort of bird's eye-view of the country, based on more or less accurately determined contours and known as "hachuring." This enabled the educated soldier to read his map with more exactness and still made it possible for his less diligent companions to understand in a general way the topographic characteristics of the ground.

As a concession to the growing necessity for more detailed information on the map, the elevations of hill-tops were written in in figures, and an elaborate system was devised of showing the relative steepness of slopes by the relative amount of black and white lines on the map, and up to the present time Germany is handicapped by this archaic system in her General Staff maps of small scale.

France has recently broken away from the hachured map, but retains its best features by so shading the contoured map as to bring out to the eye the main topographic incidents. The United States, unhampered by tradition, uses the contoured map exclusively for military purposes; England uses it almost exclusively, and the modern German soldier has a pure contoured map of his country at a scale of 2.58 inches to the mile.

An uncontoured county map, or a military sketch of whatever scale without contours, bears about the same relation to a contoured map or sketch that the smooth-bore flint-lock does to the modern high-power rifle. The hachured map is about as valuable—continuing the simile—as the earliest attempt at a rifled breech-loader.

To the American officer, who will have the maps of the U. S. Geological Survey provided for his use, if any, the contoured map is the only one of importance and is the one to which he must accustom himself and whose

details he must master. For, should a map problem be given on a hachured map, or should the fortunes of war make such a map the only one available, he, with his superior knowledge, will experience no difficulties with this antique form of hypsographic expression other than the vexation due to its imperfections.

A review of the development of the science of war, from the period of dense formations whose limited extension made it possible for the commander to personally overlook the scene of battle, up to the time of the huge Manchurian battle-fields 100 miles in length, where such personal observation was obviously impossible, will show a constantly increasing dependence by the commander on maps.

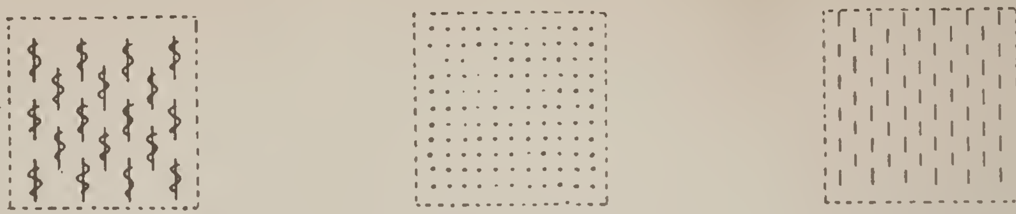
While it is true that even to-day in large armies the subordinate commanders—brigade commanders and lower—will use maps only to supplement the ground that they can see, still in small forces, acting independently, the map has become a *sine qua non*, upon which the commander will lean heavily, solving his daily prob-

lems much as, in time of peace, he solved a map problem. During the entire Russo-Japanese War there were but three of the large battles between field-armies—Liao Yang, Sha-ho, Mukden—but there were literally thousands of small engagements in which the map carried by the subordinate commanders played a vital part. The whole theater of war was elaborately mapped by both armies, and maps were issued to and used by even the company officers and their non-commissioned officers.

It is, therefore, necessary for all officers and non-commissioned officers to possess a knowledge of map-reading, and by this is meant, not an ability laboriously to dig out the meaning of the map, but an ability quickly to grasp the features of the ground from a contoured map. It is not sufficient that the officer should be able to follow a road from the map, or to determine distances; he must also know what the slopes of the ground are, the steepness of grades of the roads, the relative heights of hills, etc.—in a word, he must be able to form a perfect mental

picture of the ground and grasp its features as though he were actually on the ground itself.

This facility is not gained without much study, but the importance of the subject demands of all officers the expenditure of the time and labor necessary to attain proficiency, and the results of such diligence will well repay the officer for his labors.

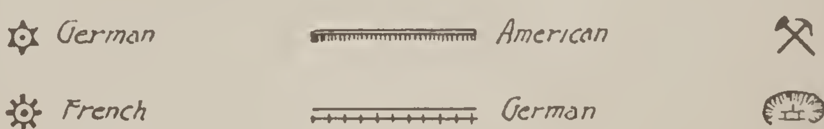


HOP FIELD | VINEYARD (FRENCH) | VINEYARD (GERMAN)

NOTE: THE ABOVE SIGNS ARE VERY COMMON ON FOREIGN MAPS. OBSERVE THE SIMILARITY BETWEEN THE AMERICAN VINEYARD AND FOREIGN HOPS.

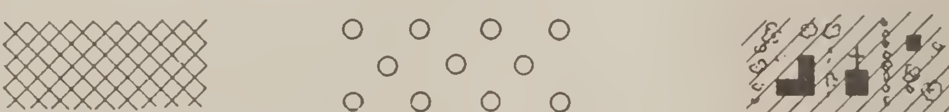
NATIONAL-BOUNDARY-LINE

GERMAN MAPS | FRENCH MAPS



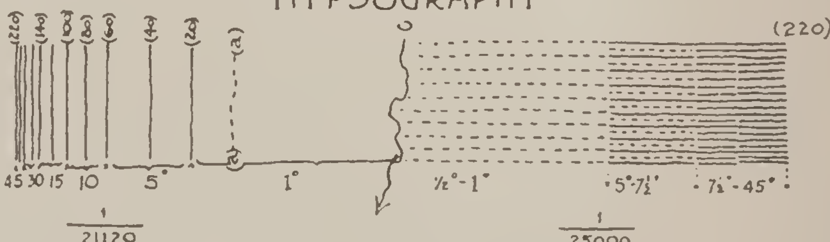
WATER MILL | TRENCHES | QUARRY

MILITARY SIGNS



OBSTACLES | MILITARY PITS | DEMOLITIONS

HYPSOGRAPHY

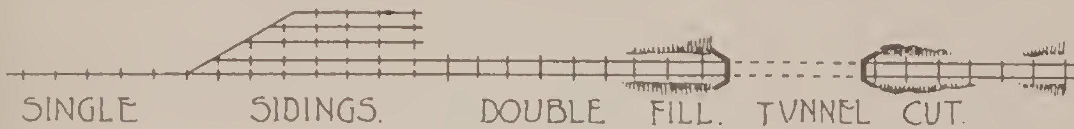


NOTE: THE ABOVE SHOWS THE SAME SLOPES EXPRESSED BY CONTOURS AND BY HACHURES (MÜFFLING SYSTEM). IN A "NORMAL" SYSTEM OF CONTOURS THE (M.D.) INTERVALS SHOWN ABOVE REMAIN THE SAME FOR ALL SCALES. IN THE $\frac{1}{100000}$ GERMAN MAPS, THE NUMBER OF LINES TO THE cm IS DOUBLE THAT SHOWN ABOVE, AND FROM 5° TO 45° THE SLOPE IS SHOWN BY SOLID LINES. OBSERVE THAT TROOPS CAN MANEUVER ON GROUND WHERE THE SLOPE IS SHOWN BY DOTTED LINES AND ONLY WITH DIFFICULTY WHERE LINES ARE SOLID.

A DOTTED CONTOUR (a a) SHOWS WHERE THE SLOPE CHANGES.

CONVENTIONAL SIGNS

RAIL ROADS

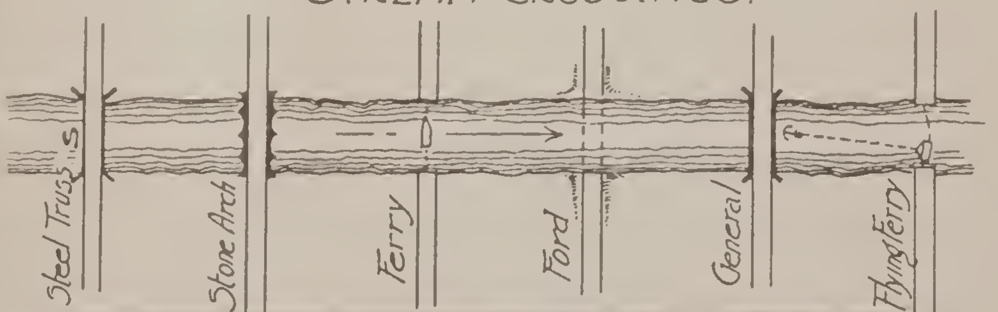


Note: On some foreign maps railroads are shown by solid red line, but where color is not used the most common signs are : for Single Track, and for Double Track

ROADS.

Note: Foreign roads of the better classes have rows of trees on both sides; the presence of these trees on a map indicates a good road, thus — . The national highways are drawn with heavy lines and inferior roads according to character, one side light, both sides light; one or both dotted.

STREAM CROSSINGS.



CULTIVATION, ETC

II.

Conventional Signs.

As a knowledge of the alphabet is necessary in reading the printed page, so is a knowledge of the topographer's alphabet necessary in reading a map. This topographer's alphabet—the conventional signs—varies with different maps and with different topographers and countries, but universally they are intended to be more or less self-explanatory, being merely a species of sign-writing, a miniature representation of the object expressed, or, if obscure and unusual, are explained in a legend. It makes little difference in the printed page whether the printing is done in Roman, Italics, or Old English type, and as little difficulty will be found with the various conventional signs unless they are quite unusual or consist of abbreviations in a foreign tongue.

The purpose of the map, the scale, the meth-

ods of reproduction, etc., all call for variations of the conventional signs; those used on the $\frac{1}{100000}$ maps of Germany would be quite impossible and out of place in a hasty military sketch made at 3 inches to the mile. The tendency in modern maps, however, is to reduce the number and variety of signs and substitute abbreviations. This presents a real difficulty in working on foreign maps, even when possessed of a slight knowledge of the language; though, of course, even a little knowledge of the language will make clear many otherwise unintelligible abbreviations. To know, for instance, that *Bahnhof* is the German word for "railroad station" makes clear at once the abbreviation *Bnf*. found beside a house on the railroad in reading a German map. The Germans also make a great point of showing the character of the roads by means of conventional signs, but, except on the Government maps, these signs vary for roads of the same character. Some of the most generally-used foreign abbreviations are given in Appendix I. and just preceding this chapter will

be found a large assortment of conventional signs.

Assuming, then, no great difficulty with the conventional signs, the essential elements of map-reading require that you should—

1. Learn to appreciate distances on the map—grasp the scale.
2. Learn to appreciate directions on the map.
3. Learn to appreciate and grasp the ground forms, slopes, and undulations expressed by the contours on a topographical map.

III.

The Scale of the Map.

All maps are made *to scale*—that is, a certain relation or ratio exists between horizontal distances on the ground and distances on the map. This relation always is, or should be, stated on the map, but custom differs with cartographers as to the method of its statement.

If, for example, a distance of 1 mile on the ground is to be represented by a distance of 1 inch on the map, the relation of map and ground distances is as 1 inch is to 1 mile, and often that simple statement is made in words and figures; *e. g.*, "Scale 1 inch = 1 mile." In other cases a graphical scale will be given—that is, (with the same scale as above, 1 inch = 1 mile), a straight line will be divided into inches and each division marked with its value from left to right, the end of the line marked "zero," the first inch division

marked "1 mile," the second marked "2 miles," etc. Since maps are often of international application where different systems of measurements would make either of these two methods awkward or inutile, and since various problems in map-reading arise which require for their solution a more convenient statement of the relation of map and ground distance, it is customary on modern maps to give the relation in a fractional form, the numerator being unity and representing map distance, and the denominator representing ground distance, expressed in the same unit of measure as that taken for the numerator. This fraction is called the "representative fraction" (usually abbreviated "R. F."), and may appear on the map in any of the following forms: $\frac{1}{20000}$; R. F. $= \frac{1}{20000}$; Scale $\frac{1}{20000}$; or Scale 1—20000; all meaning the same thing—*i. e.*, 1 inch on the map represents 20,000 inches on the ground, or that the map distances are $\frac{1}{20000}$ of the length of the ground distances.

Taking the example above considered of a map on a scale of 1 inch to the mile, the rela-

tion between map and ground distances is $\frac{1 \text{ inch}}{1 \text{ mile}}$, but to reduce this to the form of an R. F., either the numerator must be reduced to miles or the denominator to inches, since both must be in the same unit, and further, since the numerator of the R. F. is to be unity, it is evident that the mile must be reduced to inches. A mile equals 63,360 inches, so that the R. F. becomes $\frac{1}{63360}$. If the scale is n inches = 1 mile, the denominator of the R. F. is found by dividing 63,360 by n inches; *e. g.*, 3 inches = 1 mile; = R. F. $\frac{1}{21120}$.

Having reduced the R. F. in this manner, it is of no further importance that we started with inches and miles, for we are concerned only with the relation that exists between map and ground distances, and we know from the R. F. $\frac{1}{63360}$ that 1 inch on the map will represent 63,360 inches on the ground. If we measure on the map a distance of 1 foot (12 × 1 inch) we know that it will represent 12 × 63,360 inches on the ground; in other words, we can multiply both numerator and denominator by the same number without changing the value of the fraction

or the map-ground relation. The importance of this is that a foreigner, accustomed to the metric system and knowing only that the ratio of the map to the ground distances is 1—63,360, can consider the numerator as 1 meter, or 1 centimeter, or 1 decimeter, or any other unit, and, without computation, he knows that the denominator is also 63,360 meters, or centimeters, or decimeters, etc. Conversely, a foreign map made with a ratio of 1 centimeter to 250 meters (= 25,000 centimeters), and so bearing the R. F. $\frac{1}{25000}$, is intelligible to us, for we read the ratio as 1 inch = 25,000 inches, and ignore the system of measurement used in the construction of the map, as we may do, since we know that the map is $\frac{1}{25000}$ of the size of the ground.

Before we can measure distances on a map we must have a graphical scale in units with which we are familiar and in which we wish to know the distances, as in yards or miles. If the relation of map and ground distances is expressed in words and figures, we must first deduce the R. F. in the manner indicated; if a graphical scale only

is given and that in unknown units, such as Prussian fuss, meters, etc., we must first find the length in familiar units of a Prussian fuss, a meter, etc., and then either construct the desired scale graphically or deduce the R. F.

Having obtained the R. F., the problem of constructing a graphical scale becomes a simple matter of arithmetic. Suppose the R. F. is $\frac{1}{63360}$, and we wish a scale to read yards. We know that 1 inch on the map represents 63,360 inches on the ground, and that, since there are 36 inches in 1 yard, 1 inch will represent as many yards as 36 is contained times in 63,360, or 1,760 yards. An inch scale, with its divisions marked zero, 1,760, 3,520, 5,280 yards, etc., may at once be made, but this would be an inconvenient scale to use, for with it we could measure these and no other distances. The problem, then, becomes one of constructing a scale with which we can measure any distance to within say 100 yards. Now, if 1,760 yards are represented by 1 inch, 5,000 yards will be represented by a line as much longer than 1 inch as 5,000 is greater

than 1,760—that is, 1 inch : x inches :: 1,760 : 5,000, from which $x = 2.84$ inches.

Consideration of the above proportion will show that the first terms (1 : x inches) will remain constant in any and all problems, and that the value of x can always be found by dividing the desired number of units by the number of similar units represented by 1 inch. From the first and second steps of the problem above detailed we can form the following simple rules for constructing a graphical scale from a given R. F.:

(*a*) Divide the denominator of the R. F. by the number of inches in the desired unit of measure.

(*b*) Divide the desired whole reading of the scale by the quotient found by (*a*), the result will be the length in inches of a line representing the desired whole reading of the scale.

Example.—The detailed maps of Germany are made with an R. F. of $\frac{1}{25000}$. Required a scale of yards:

(*a*) $\frac{25000}{36} = 694.44$

(*b*) $\frac{3500}{694.44} = 5.03$

A line 5.03 inches long on the map will represent 3,500 yards on the ground. Even this may be simplified and the sometimes long arithmetical calculations avoided by performing both (*a*) and (*b*) at the same time, thus:

$$\frac{\frac{3500}{25000}}{36} = \frac{3500}{1} \times \frac{36}{25000} = \frac{126}{25} = 5.03$$

The question of how long to make the scale is involved in the above examples, in the first of which 5,000 yards was arbitrarily chosen and in the latter 3,500 yards. Of course, the only importance the question can have is, whether the resulting length of line will be long enough for the probable use of the scale, for if too short, troublesome repetitions of measurement become necessary, and if too long, the division into smaller parts is awkward. The student should not be misled into the belief that "about 3 inches," or "4" or "6" inches is the correct length for a scale, but rather from a knowledge of the probable use of the scale, and above all from experience, settle each case on its own merits. If, as in the last example, a line about 5

inches long is desired, it is seen from inspection that if 1 inch = 694.44 yards (nearly 700 yards), a line 5 inches long will represent a little less than 5 × 700 or 3,500 yards, which was the length chosen above. If, on the other hand, the use of the scale will be such as to seldom call for measurements of over 3,000 yards—as in taking off rifle-ranges—3,000 or 3,500 yards is chosen, and the resulting length is allowed to work itself out.

With the whole length known (5.03 inches = 3,500 yards) and a line 5.03 inches long drawn, it still remains to divide that line into convenient graduations. This may be done by calculation or graphically; in either case the graduations would be so placed as to read whole numbers, as 500 or 1,000 yards, and the left-hand division, equal in length to the others, would be still further subdivided to read to as small a distance as possible in view of the scale of the map. Let us say that the main divisions are to be 500 yards apart; then, since 3,500 yards are shown by a map distance of 5.03 inches, 500 yards would be shown by $\frac{1}{7}$ of 5.03 inches, or 0.72 of an

inch. Draw a line and mark, with the aid of a scale of $\frac{1}{100}$ or $\frac{1}{10}$ inch parts, a series of points 0.72 inch apart from left to right, each of which will represent 500 yards. Mark the left end of the line 500, the first division 0, the second 500 yards, the third 1,000 yards, etc., to the right-hand end. Now divide the left-hand space into five parts, each $\frac{1}{5}$ of the length representing 500 yards ($\frac{.72}{5} = .145$) and each representing $\frac{1}{5}$ of 500 yards, or 100 yards, and mark them successively 400, 300, 200, 100 yards, as indicated below:

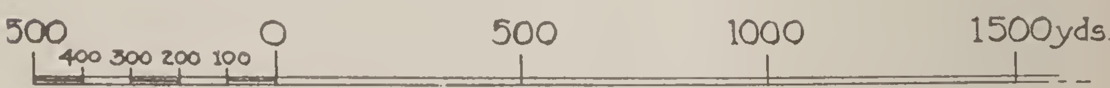
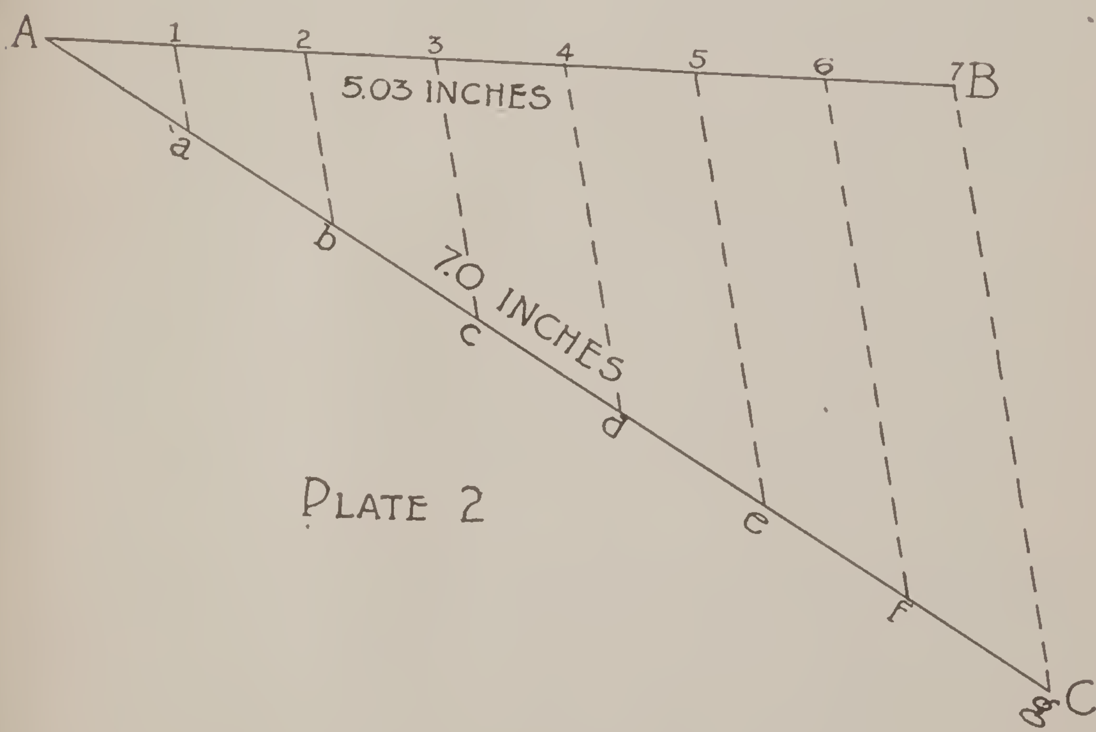


PLATE 1

If lacking a suitable scale of equal parts, divide the 5.03-inch line into seven equal parts graphically and similarly subdivide the left division into five parts.

The principle upon which this graphical division is based is that of similar triangles whose

sides are always proportional. Therefore, if we form a triangle with one side 5.03 inches long and the opposite side 7 inches long, we can construct seven similar triangles within it whose sides will be proportional:



Draw the horizontal line AB 5.03 inches long, and at any convenient angle with it draw AC 7 inches long, and connect B and C. The line AC is easily divided into seven divisions by the inch scale, as shown at *a*, *b*, *c*, *d*, *e*, *f*, and *g*. Draw-

ing lines parallel to BC from these points, as indicated by the dotted lines in the figure will form seven similar triangles, in the first of which the side A*a* will be to the side AC as $\frac{1}{7}$ by construction; the other sides will bear the same relation to the triangle ABC, and the distance A1 will therefore be to the distance AB as $\frac{1}{7}$; the second triangle will be $\frac{2}{7}$, etc., to the end.

In this construction the line *a*1 is $\frac{1}{7}$ of BC, etc., but the length of the side BC does not enter into the problem, and it is immaterial what the length of that side has been made, or, which is the same thing, at what angle AC is drawn with reference to AB. The important thing is to make AC of such a length (not too widely differing from AB) that it shall be readily divisible into the desired number of parts and that the parallel lines be truly parallel, for otherwise the triangles will not be similar nor the sides proportional.

In deducing the R. F. from the form of a statement, it should be observed that while no rule exists as to the relative position of map and

ground distances, the part of the statement which gives the map distance can always be known by the relative smallness of the unit in which it is expressed. Thus the expressions "3 inches = 1 mile" and "3 miles = 1 inch" are both correctly expressed, although the position of the map distance with reference to the sign of equation is exactly reversed. The expressions cannot well be misunderstood, however, since it would be manifestly impossible to measure miles on the map to find inches on the ground. Representing the same ground, the first map would be nine times as large as the second.

It has been stated that where the number of inches to one mile is given, the R. F. is found by *dividing* 63,360 (inches in one mile) by the number of inches to the mile of the scale; *e. g.*, Scale 3 inches = 1 mile, $\frac{63360}{3} = 21{,}120$; R. F. = $\frac{1}{21120}$.

Where, however, the number of miles to the inch is given, the R. F. is found by *multiplying* 63,360 by the number of miles to the inch; *e. g.*,

3 miles = 1 inch, $63{,}360 \times 3 = 190{,}080$; R. F. $= \frac{1}{190080}$.

Another case will arise, however, where the R. F. is given and it is desired to know (1) the number of inches to the mile, or (2) miles to the inch. (1) Divide 63,360 by the denominator of the R. F., or (2) divide the denominator of the R. F. by 63,360; for example:

(1) R. F. $\frac{1}{21120} = \frac{63360}{21120} = 3$ inches to 1 mile.

(2) R. F. $\frac{1}{190080} = \frac{190080}{63360} = 3$ miles to 1 inch.

Under the second system of scale statement —the graphical scale—it has been stated that the length of the new scale in familiar units may be found graphically or by computation. For example, a foreign map has only a graphical scale of versts. By reference to a table of comparative measures a verst is found to equal 0.6629 statute miles. The scale is then measured, and it is found that a distance of 5 versts is represented by 2.1 inches. If 2.1 inches = 5 versts, 1 inch will represent $\frac{5}{2.1}$ versts, or 2.38 versts. A verst is 0.6629 statute miles long, or $0.6629 \times 63{,}360$ inches $= 42{,}001.344$ inches,

which we may call 42,000, and if 1 inch = 2.38 versts, as above, it will equal $2.38 \times 42{,}000 =$ 99,960 inches, and the R. F. is $\frac{1}{99960}$.

In the foregoing computation we disregarded the smaller decimal places, in view of which and of the fact that the R. F. is seldom a fractional number, such as 99,960 (which differs from 100,000 by only 40), it is evident that the R. F. is $\frac{1}{100000}$, and this may be verified by carrying out each result to say four decimal places, when the R. F. will be found to be $\frac{1}{99999.9999295}$.

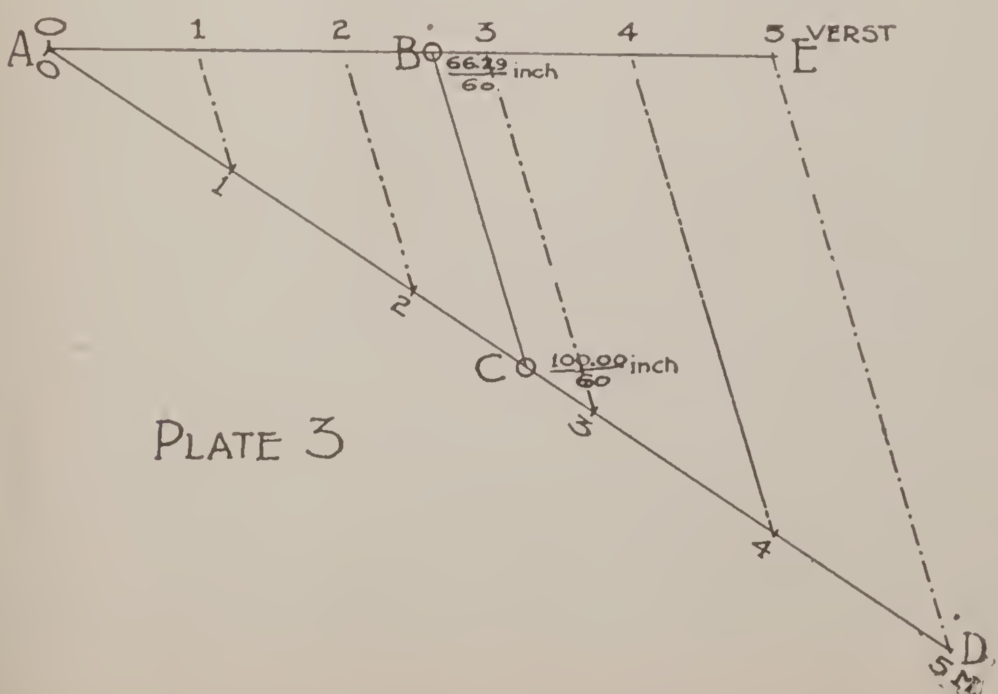


PLATE 3

Graphically, the solution is simpler (Plate 3): Reproduce the given scale of versts on a horizontal line; measure on this line, using any scale of equal parts 6.629 divisions (AB); draw at any angle the line AD and lay off 10 divisions (AC); connect B and C. A line parallel to BC at the 5-verst mark prolonged to meet AD will give the distance AD as 5 miles. Smaller divisions of the verst scale are converted into miles by a series of parallel lines, as indicated.

From the properties of similar triangles it is seen that the distance AE (= 5 versts) bears the same relation to AD (5 miles) as 0.6629 mile (value of 1 verst) does to 1 statute mile.

Thus far we have considered only graphical scales reading units of linear measure. It is often necessary, however, especially in map problems or in map maneuvers, to construct scales that shall read minutes of time marching. This introduces no new principle, but an application only of those explained. For example, it is desired to construct a scale of minutes for infantry marching, and it is assumed that infantry

marches 2 1-2 miles per hour, including halts. The R. F. is $\frac{1}{21120}$. At this scale 1 mile is shown by 3 inches and $2\frac{1}{2}$ miles by $2\frac{1}{2} \times 3 = 7.5$ inches. Draw a line 7.5 inches long and divide it as desired—into 4 parts to show 15 minutes each, the left division subdivided into 3 parts to show 5 minutes, or divide it into 12 parts to show 5 minutes each, the left space divided into 5 parts showing single minutes. The length in inches of the spaces in the latter case will be $\frac{7.5}{12} = .625$ inch, and in the former $\frac{7.5}{4} = 1.875$ inches.

If a scale of yards has been prepared, it will be easier, perhaps, to find the number of yards traveled in 1 minute and to lay off this distance with the scale of yards. Thus: 2.5 miles = 4,400 yards ($2.5 \times 1{,}760$), and $\frac{4400}{60} = 73\frac{1}{3}$ yards traveled in 1 minute. This is too small to lay off with accuracy, so lay off 367 yards to show 5 minutes ($5 \times 73\frac{1}{3} — 367$).

Having by one of these methods constructed a scale on a strip of paper, distances are measured by applying the scale to the required por-

tion of the map, placing one of the divisions of the main scale opposite the right-hand end of the line to be measured and adding to the reading of this whole number such fractional part as the subsidiary scale shall indicate.

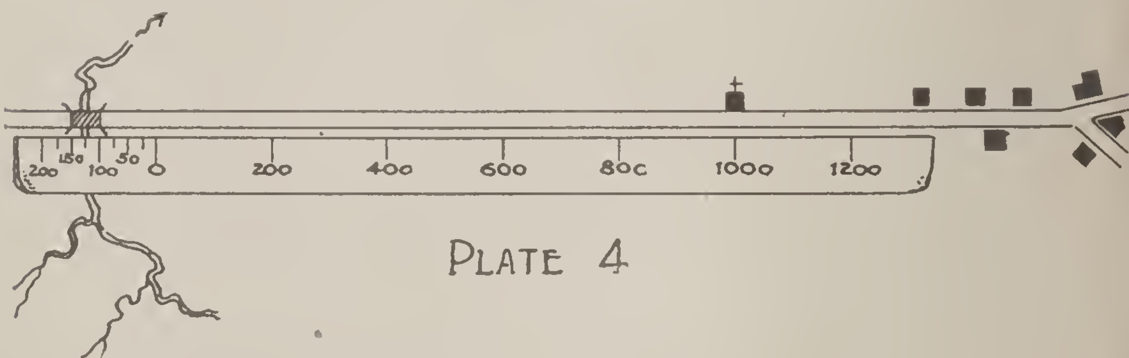


PLATE 4

In Plate 4 it is desired to read the distance from the bridge to the church. Placing 800 at the church, the left end of the scale does not reach the bridge; with 1,200 at the church, the zero is beyond the bridge; but with the 1,000-yard division at the church, the bridge is opposite the secondary scale, as it should be, and a closer inspection shows it to be opposite the graduation of 125 yards; this, added to the 1,000 yards of the main scale, gives the whole distance as 1,125 yards. This will make it plain

why the secondary scale covers one complete division of the main scale and why it is numbered in the reverse direction.

Distances are measured on a map in the manner indicated, only when the absolute distance is required and the scale has been constructed on or transferred to a strip of paper. In practice, if a graphical scale is on the map, it is customary to use a pair of dividers to transfer the distance from the map to the scale. Dividers cost from 5 cents to $5.00, according to design —and the 5-cent kind will prove about as satisfactory as the more expensive for this class of work. In using dividers, one leg or point is placed on one extremity of the line to be measured and the dividers are opened until the other leg rests on the other extremity; then, being careful that no further movement takes place in the instrument, the points of the dividers are placed, one at the proper division of the main scale, the other falling on the secondary scale, and the distance read as explained for a portable scale.

Where the distance to be measured is not along a straight line, as where it is desired to know the distance along a winding road, each straight section must be considered by itself and the lengths of the successive straight sections added. With dividers this is done by first extending the dividers to include the first straight stretch, then pivot the instrument on that leg which rests on the road's first change of direction until the plane containing the two legs also contains the second section of road; the free leg is then placed on the paper, the pivot leg raised and extended to the next turn, etc., to the end.

In Plate 5 it is desired to measure the road distance from *a* to *d*. (1) Open the dividers from *a* to *b*, pivot on *b* until the free leg lies in prolongation of *bc* (at a') and set it there, lifting the leg from *b*; (2) open the legs still wider to include $a'c$, pivot on *c* until the left leg rests at a'', open to *d*. The distance from one leg to the other will now be the whole (road) distance from *a* to *d*, which may be referred to the graphical scale, as explained.

Using a portable scale, the same method is followed: Lay the scale along the road from *a* to *b*, the zero of the scale at *a*, holding the scale at *b* by a pin or pencil-point, turn it on *b* until it lies along *bc*, pivot again at *c*, and mark on the map the position and value of the last main division between *c* and *d*; read the distance from this mark to *d* by the secondary scale, and add to the whole reading.

When much of this sort of measuring is required, the process becomes tedious and is simplified by using a curvimeter, or map-measurer. The curvimeter is an instrument having a small wheel, which is rolled along the road, its motion translated through a train of wheels within the case to a pointer like a watch-hand. This pointer moves around a dial graduated, usually, so as to record the distance in inches and also in centimeters traveled by the instrument along the road. The ground distance may thus be computed if desired, or, moving the instrument along the graphical scale in an opposite direction, the hand will return to zero when it has trav-

eled the original distance. By noting this distance on the graphical scale, its value in ground distance becomes at once known. Curvimeters are made in two patterns, one having a small pencil-like handle and the other the general form of a small watch. They cost from $1.25 to $2.00, and are very convenient.

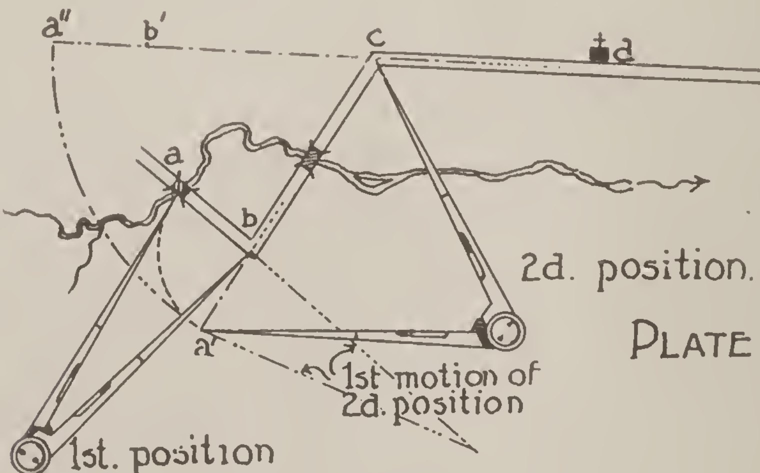


PLATE 5.

Having thus constructed a graphical scale, familiarize yourself with it, master it; practice by estimating the distance from one point on the map to another, and check your estimate by the scale. Ask yourself, "Is this point within artillery range from that hill?" "Is this house within effective infantry range of the bridge?"

"How long would it take infantry to march from 'here to there'?" etc. Make your estimate, check it by the scale, and continue and repeat until you are able to estimate the distance with an error not greater than $\frac{1}{8}$ of the true distance.

In this way you will soon be able to scale distances with the eye with surprising precision—an important and vital step towards proficiency in map-reading. Having mastered the scale of a large-scale map, but not before, take up a small-scale map and repeat; return to the large scale, and alternate until varying scales present no difficulty to you.

EXAMPLES.

1. The scale of a map is 1 inch to the mile. What is its R. F.?

2. The scale of a map is 4 inches to the mile. What is its R. F.?

Answer: $\frac{63360}{4} = 15{,}840$: R. F. $= \frac{1}{15840}$.

3. The scale of a map is 5 miles to the inch. What is its R. F.?

Answer: $63{,}360 \times 5 = 316{,}800$: R. F. $\frac{1}{316800}$.

4. The scale of a map is $2\frac{1}{2}$ miles to the inch. What is its R. F.?

5. The R. F. of a map is $\frac{1}{62500}$. Express the scale in inches to the mile.

Answer: R. F. $= \frac{1}{62500} = \frac{63360}{62500} = 1.012$ inches to the mile.

6. The R. F. of a Japanese map is $\frac{1}{25000}$. Express the scale in inches to the mile.

7. The R. F. of the German General Staff map is $\frac{1}{100000}$. Express the scale in miles to the inch.

Answer: R. F. $= \frac{1}{100000} = \frac{100000}{63360} = 1.58$ miles to the inch.

8. Express the R. F. $\frac{1}{100000}$ in inches to the mile.

9. The R. F. of a map is given as $\frac{1}{125000}$. Construct a graphical scale to read miles.

10. The R. F. is given as $\frac{1}{32120}$. Construct a graphical scale to read yards.

11. A German map bears the following scale of German geographical miles. Construct a scale to read statute miles (English). *Note.*

— 1 German geographical mile = 4.61 miles (statute).

GEOGRAPHISCHE MEILE.

12. On a portion of the map of Fort Leavenworth the distance along Grant Avenue from Augur Avenue to Metropolitan Avenue is found to be 19.7 inches. It is known that this distance on the ground is 8,668 feet. What is the R. F. of the map?

Answer: $\frac{19.7 \text{ inches}}{8668 \text{ feet}} = \frac{19.7 \text{ inches}}{8668 \times 12 \text{ inches}} = \frac{19.7}{104016} = \frac{1}{5280}$ = R. F.

13. Draw a scale to show minutes of cavalry marching, trot and walk alternating (5 miles per hour), for the above map of Fort Leavenworth.

14. How many inches to the mile is the above Fort Leavenworth map?

IV.

The Determination of Directions.

Having mastered the scale of the map, the next matter that will demand your attention is that of directions. Note the meridians of the map, both true and magnetic, if both are shown, and pay particular attention to the magnetic meridian, since it is this line of reference that is used with the compass, and not the true meridian. In map-reading indoors, or even in field map-reading, unless the position of the magnetic meridian is quite at variance with the true, it will be sufficient to refer directions roughly to the true meridian, though, as will be explained later, the magnetic meridian may be the only one that should be used, under certain circumstances.

In Government maps, and indeed in most maps, no meridian at all is drawn, the side

border-lines serving as such, or even the lettering, which is done on an east-and-west line. A small triangle and a note, both showing the magnetic variation often appear in the margin, especially on Government maps.

There are two methods of graduating the compass circle: (1) into degrees and (2) into "cardinal points."

(1) The whole circle, divided into 360 equal parts, each of which will represent a "degree" (shown thus: °), is used in map-making and sometimes in map-reading.

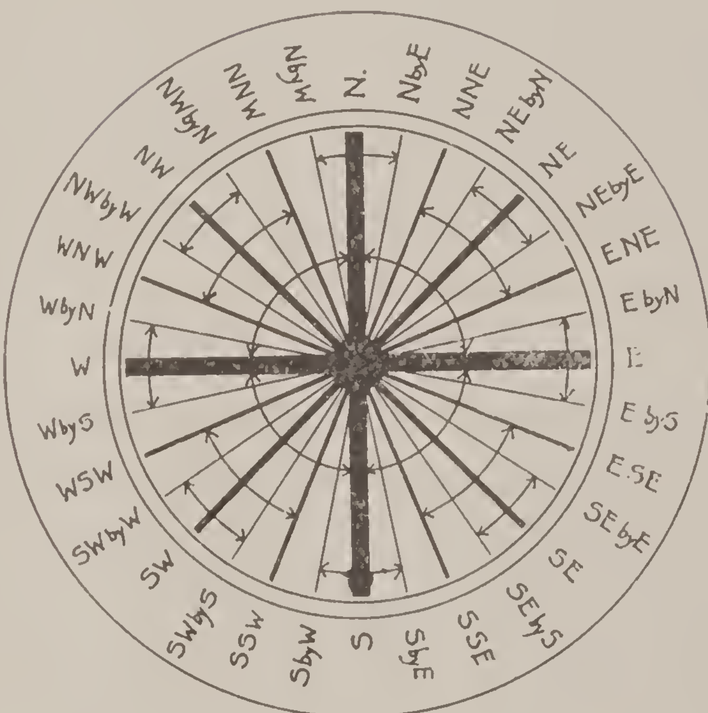
(2) The whole circle, divided into 32 parts, each of which represents a "point," is used in map-reading and in orders, but never in map-making. Each point is equal to $11\frac{1}{4}°$ ($\frac{360}{32} = 11\frac{1}{4}$), and with this knowledge it is easy to convert "points" to "degrees," and *vice versa*.

A reference to the following plate will show that the primary divisions are 4: N., S., E., and W. The intervals between these points are divided, producing 4 more points: N. E., S. E., S. W., and N. W. The intervals between these

secondary divisions are again divided, and these are named, with reference to the secondary divisions, N. E., S. E, etc. Thus the point midway between the N. and N. E. points is called N. N. E.; that between the N. E. and E. points is called E. N. E., etc. Lastly, the intervals between the 16 points described are divided into what are called the "by" points, since the word "by" occurs in all of them, and, on the principle that as they are on or by the N., S., E., or W. of the first 8 divisions, they are designated that division "by N.," "by E.," etc. Thus, on each side of the N. point is a "by" point, one being N. by E., the other N. by W. Beside the N. E. point are the N. E. by N. and the N. E. by E. points, etc.

In map-reading it is seldom necessary to be so exact as to require the use of the "by" points, and when the occasion does arrive, it is best to give the direction in degrees. The cardinal points will frequently be used to the first 8 divisions, and in special cases to the first 16 points.

Having found the meridian, draw one across the map to guide you in practicing estimating directions. Mark a spot on the map where you



MARINERS COMPASS
SHOWING DIVISION INTO POINTS

suppose yourself to be, and imagine a circle centered there with the cardinal points on it. Estimate the direction in terms of the cardinal points of the compass, and check your estimate. This you can do if you first orient the map and

then apply the compass to the assumed station, making the sighting-line on the box-lid point to the spot to which you have estimated the direction. To orient the map, lay it on a table, place the north-south line of the compass parallel to the meridian, and revolve the map and compass together until the needle points to the zero of the compass. The map is now oriented, and should not be disturbed. Having estimated a direction, lift the compass to the spot you marked as being your location, and sight along the line on the lid of the box (moving the compass, but not the map) until it points to the place and shows the error, if any, of your estimate.

Repeat this operation until you can speak with certainty of the "ridge 1,500 yards N.N.E. of our position," etc., for nothing causes so much confusion as looseness in speaking of directions—saying "south of Hill 296" when "south-west of Hill 296" is meant, or "south-west" when "south-south-west" is meant.

Combine the exercises in estimating distance

with those of estimating directions as a matter of further practice.

The real difficulties of map-reading come after these preliminaries—questions of relative heights, undulations of the ground, steepness of slopes, visibility of one point from another, etc. A knowledge of the principles of contouring is necessary to enable one to understand this part of map-reading.

Contours serve three great purposes:

1. They show the elevation of any given point on the ground with respect to all other points.
2. They graphically represent the general undulations of the ground.
3. They show the inclination of slopes, both in general terms of steepness and in absolute degrees of slope.

The elevation of any point, if on a contour, is that of the contour, and the difference of elevation between two points, each of which is on a contour, is the difference of elevation of those

contours. The elevation of a point not on a contour is proportional to its distance from a contour. Thus, a point half way between the 820 and 840 contours would be 830, or $\frac{1}{2}$ the contour interval above the lower contour. If the point is $\frac{1}{4}$ the distance and nearest the 820 contour, its elevation would be 825, or $\frac{1}{4}$ of a contour interval higher than 820.

Here, as in the third service of contours, it is necessary to understand that in contouring it is assumed that the slope of the ground between two adjacent contours is uniform. This is not really the case, and a slight error is introduced by the assumption, the error diminishing as the contour interval decreases, but the error is so small for a suitably contoured map that it may well be neglected.

V.

CONTOURING.

CONTOURING is a method of exhibiting relief of ground by means of lines so drawn on a map as to indicate points of equal elevation. The lines so drawn on a map are called "contours." The difference of elevation of points on adjacent

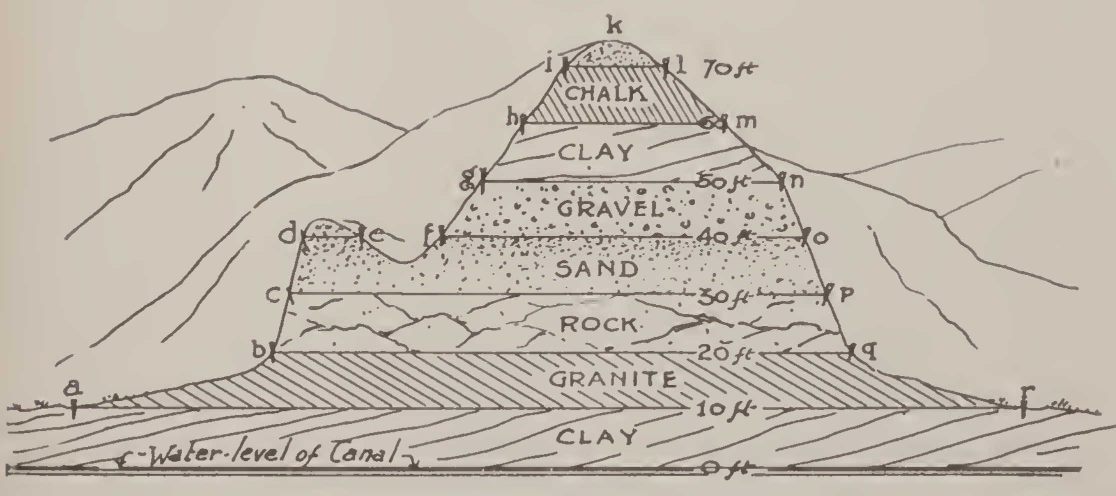


PLATE 6.

contours is called the "contour interval," and is usually constant for all the contours on the same map.

Suppose that in digging a canal a hill were encountered, and that in cutting through the hill the sides of the cut were made perfectly vertical. One riding on the canal would see one of the banks much as is shown in Plate 6, where the various strata of rock are clearly seen. Let us suppose that the strata are all of uniform thickness—say ten feet each, and that they lie perfectly horizontal, as shown.

The drawing of this side of the cut would be a *section* of the hill along the line of the canal, and by examining it we can see the steepness of the slopes at any point. It is manifestly impossible for a surveyor to go about digging canals in order to secure slope and elevation data for making his map, and even if we assume that he has, by any method, gained the necessary information, it is still necessary that he should devise a way of showing that information on the map.

Suppose that he has located the point *a* on his map, which is where the bottom of the granite stratum crops out. He might drive a stake

at *a* and proceed to *b*, the top of the granite stratum, drive another stake and locate it on his map, and so proceed to the top, driving stakes at each stratum and plotting the positions of the stakes on his map until he has reached the top of the hill. His plot would look like this:

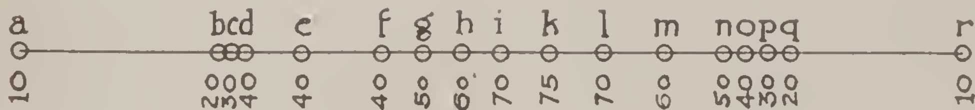


PLATE 7.

a would be 10 feet above the level of the canal, *b* 10 feet higher or 20 feet above the canal, *c* 30 feet, *d* 40 feet; *e* and *f* are on the same level as *d* and so are each 40 feet above the water, *g* is 50 feet, *h* 60, *i* 70, and *k* 75. Now, going down the other side, *l* is level with *i* and is therefore 70 feet, *m* is level with *h* and so 60, *n* is 50, *o* 40, *p* 30, *q* 20, and *r* is 10 feet above the water-level. All this is shown in Plate 7 by the figures 10, 20, 30, etc., opposite the plan of each stake.

If, having located and plotted his stakes, as

explained, the surveyor moves 10 feet to the right or left and repeats the operation on a parallel line, his map would perhaps look like this

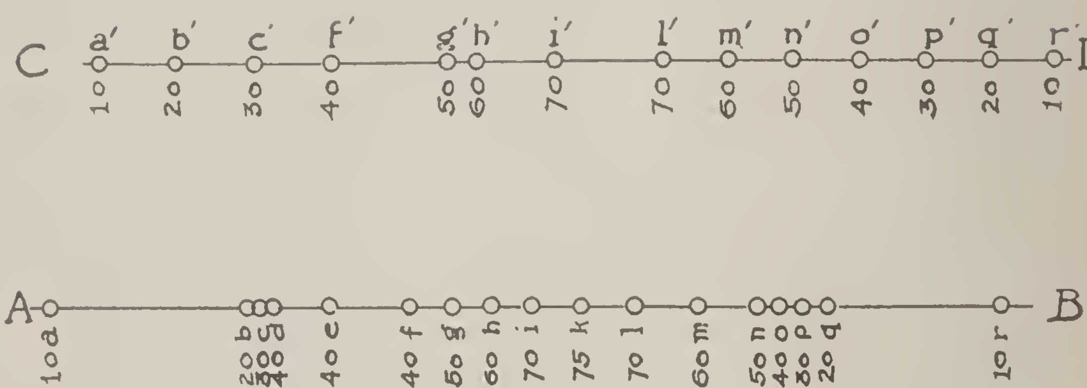


PLATE 8.

The last section would, of course, be different from the first, but *a* and *a′* would be on the same level, and if a line were drawn connecting them, every point on that line would have the same elevation as *a* or *a′*—*i. e.*, 10 feet above the water of the canal, and such a line would be a contour. If every point on the first section were similarly joined to every point of same level on the second section, what has been said of the line *a a′* would be true of those other joining lines, which would be 20, 30, 40, etc.,

feet above the water, and the map would look like this:

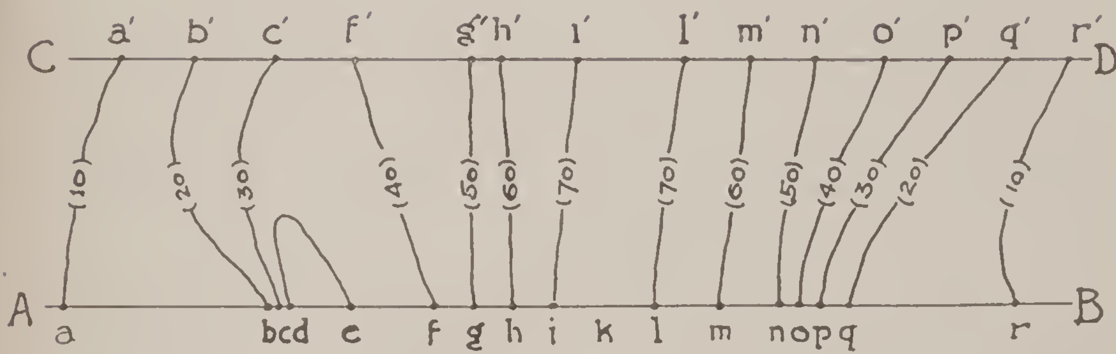


PLATE 9.

a and *a′* can be connected, *b* and *b′*, *c* and *c′*, but the two 40-foot levels at *d* and at *e* do not extend to the new line; *f* and *f′* can be joined and all of the others. Now, looking at Plates 6 to 9, let us see what we can find out of the slopes by an inspection of Plate 9.

The slope (Plate 6) from *a* to *b* is rather gentle; in Plate 9 these stakes are shown far apart. From *b* to *c* (Plate 6) the slope is steep, and in Plate 9 the stakes are near together. A further comparison will show that this is a general rule—gentle slopes and distant stakes, steep slopes and

close stakes; verify this by the slopes from *l* to *n* as compared with those from *n* to *q* on the line AB.

Looking now at Plate 9, imagine yourself starting at A to walk to B. First you walk up a gentle slope to *b*, where the slope grows steeper as far as *d*. From *d* to *f* is nearly level, but from the existence of the stakes at *d*, *e*, and *f* we know that the ground half-way between *d* and *e* must be either a little higher or lower than *d* and *e*; as you have been going up a hill, it is evidently a little higher, but not high enough to receive the 50-foot stake. Having passed this hill-crest, you have to go down to reach *e* and you can see that beyond *f* the slope is rising; therefore, you will go down to a point beyond *e*, but not far enough to receive a 30-foot stake, and, having passed this lowest point, you begin to ascend to *f* (Plate 10).

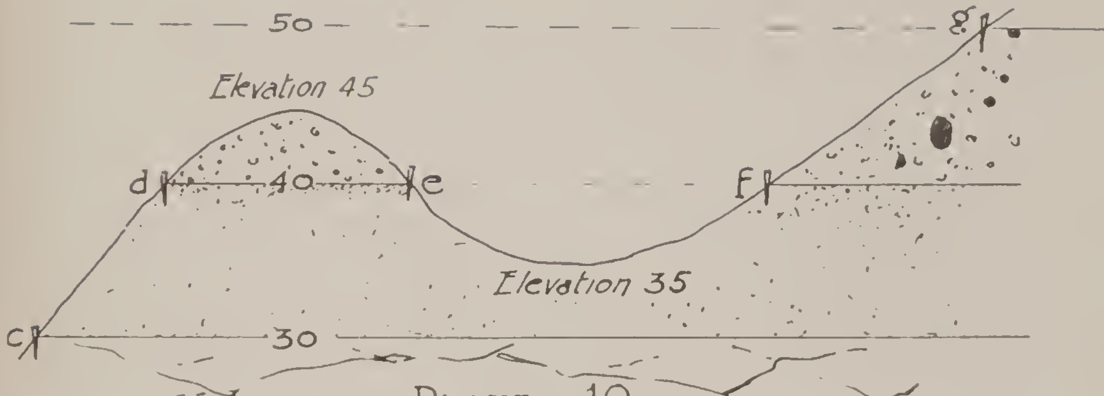


PLATE 10

From f to k, the top of the hill, the stakes f, g, h, and i are about the same distance apart, and so the slopes between them are about the same. You will go from k to n along a practically uniform slope, but from n to q the slope will be quite steep, growing gentle again between q and r. The use of the section (Plate 6) assists in seeing these slopes along the line AB, but now start at C and go to D; here you have no section to help you, yet you can see that from a' to k' is an unbroken slope, since no elevation appears more than once, as was the case at d, e, and f on the line AB; and, further, that from a' to f' the stakes are uniformly spaced and so show a uniform slope. The distance from f' to g' is a little

greater, hence the slope at this point is gentler. The stakes g' and h' are closer together than any that we have considered on this line, and hence show that the slope at this point is the steepest yet met. From h' to i' is about the same as from a' to b', b' to c', etc., and you know that the slope here is about the same as that where you started. i' and l' are on the same level, and, by the argument presented when we passed from d to e on the first line (AB), you know that you are passing a hilltop, ascending somewhat higher than 70 at i' and then descending again to that level at l'. From here to the bottom of the hill the stakes are uniformly spaced, and so the slope must be uniform.

If you draw a line midway between A–B and C–D on Plate 9, you can tell what the slopes are along that line in a similar manner. Now, a contoured map is exactly what we have been working with, and taking such a map, drawing a line on it at random, you will be able to read the slopes passed, just as you have read them on Plate 9.

If we were content to know only this: that "here the slope is steep and there gentle," we might stop here, but ideas of steepness differ, and, for application of the known effect of a certain steepness on the movements of troops, we must know exactly *how* steep the slope is at any given point. In Plate 9 we saw that the slope from *b* to *c* was steeper than that from *a* to *b*, because, when we compared the distance *b–c* with *a–b*, it was seen to be less than *a–b*. If the slope from *a* to *b* is known to be exactly 1°, then the slope *b–c* is greater (steeper) than 1°; and if on the edge of a card you had a scale showing how far apart the stakes (contours) would be for every slope from, say 1° to 10°, you could try first one and then another of these scale distances until you found one that was exactly the distance of *b* to *c*, which, let us suppose, is marked on your card-scale as representing the distance apart of contours on a 7° slope. The slope from *b* to *c* would be a 7° slope, and similarly you could find the degree of slope at any point on the map. Such a scale is called a "scale of map distances" (ab-

breviated "M. D."), and can be made for any map when the thickness of the strata (called the "vertical interval" or "contour interval," and usually abbreviated "V. I.") and the R. F. of the map are known.

All map distances are measured and drawn as though the ground were a level plain. In walking up a steep slope you may actually travel a mile, measured along the sloping ground, but the plotted or map distance would not be a mile, but the horizontal distance corresponding to a

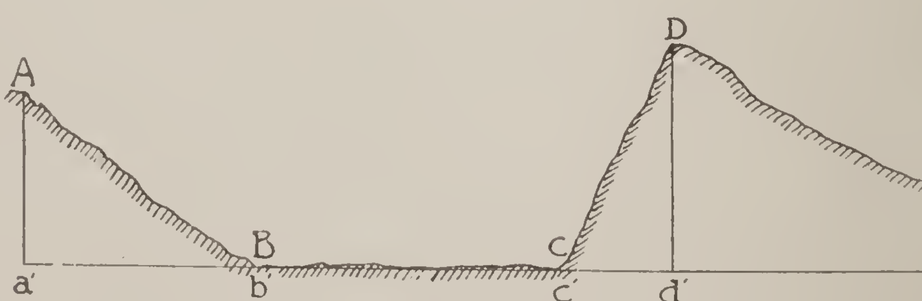


PLATE 11

mile at that slope. Thus, in Plate 11 you may walk from A to B, but the map distance from the crest of the hill to the bottom of the valley will be a'–b', and if that distance at the scale of

the map represented $\frac{3}{4}$ mile, it would be said that you had traveled $\frac{3}{4}$ mile, regardless of the slope or of the sloping distance that you actually may have traveled. When the ground is level, as from B to C, the map and ground distance will be the same, while on very steep ground, as from C to D, the map distance *c′–d′* may be much less than the sloping distance actually traveled. It will be seen that the converse of this proposition is true—that is, that on varying slopes the map distance from the bottom to the top of the slope is least on steep slopes, and approaches the maximum of distance as it approaches the level—in a word, it varies inversely with the slopes.

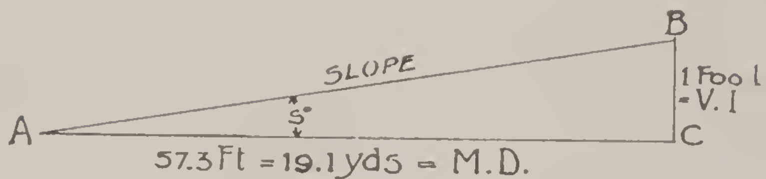
Every slope can, therefore, be considered as a right triangle, its base, the map distance (*a′–b′*, Plate 11), its altitude, the elevation of the top of the hill above the bottom (A–*a′*), its hypothenuse, the slope of the ground (A–B), and the angle at B, the degree of slope.

Now it is known that if the angle at B *is* 1° *and the elevation* A–a′ *is* 1 *foot, the distance from*

a′ to b′ will be 57.3 feet. A triangle of these dimensions is called the "triangle of reference," since from it all questions dealing with slopes may be solved.

If, for example, the slope c'–d' (Plate 11) is 10°, and the distance D–d' is 1 foot, the map distance c'–d' will be $\frac{1}{10}$ of 57.3 feet, or 5.73 feet. Again, if the slope is 10° and the map distance is 57.3 feet, the altitude D–d' will be 10 × 1 foot, or 10 feet. And, lastly, if the map distance c'–d' is 57.3 feet and the altitude (d'–D) is 10 feet, the angle of slope will be 10°; for if we divide the map distance 57.3 feet, which corresponds to a rise of 10 feet in the slope considered, by 10, it will give us 5.73 feet as the map distance corresponding to a 1-foot rise. In the triangle of reference we know that a rise of 1 foot to 1° gives a map distance of 57.3 feet, so that the slope under consideration will be found by dividing 57.3 feet by 5.73 feet, and the slope is therefore 10°, as stated.

TRIANGLE OF REFERENCE.



THE TRIANGLE OF REFERENCE
PLATE 12

Formulæ.

S° = *Degree of slope.* (*Hypothenuse AB.*)
V.I. = *Rise in feet.* (*Altitude BC.*)
M.D. = *Map distance in feet.* (*Base AC.*)

$$\text{M.D.} = \frac{57.3 \times \text{V.I.}}{S^\circ} = \frac{19.1 \text{ yds.} \times \text{V.I.}}{S^\circ}$$

$$\text{V.I.} = \frac{\text{M.D.} \times S^\circ}{57.3} = \frac{\text{M.D. (yds.)} \times S^\circ}{19.1 \text{ yds}}$$

$$S^\circ = \frac{57.3 \times \text{V.I.}}{\text{M.D.}} = \frac{19.1 \text{ yds} \times \text{V.I.}}{\text{M.D. (yds.)}}$$

All of the foregoing will be seen by reference to Plate 12 and its accompanying formulæ. It will be observed that the dimensions of the V. I. and M. D. are both in the same unit, but when in any problem the M. D. is given in yards and the V. I. in feet, as is often the case, it is only necessary to reduce the 57.3 feet of the triangle

of reference to yards (= 19.1 yards), as was done in the second column of the above formulæ.

With this knowledge of the triangle of reference, we may read the slope at any part of a contoured map in one of three ways:

1. By a scale of yards and a calculation with the above formulæ.

2. By a scale of inches, suitably subdivided, and a calculation using the above formulæ.

3. By a scale of M. D.s, showing the distance apart of contours at the various slopes; such a scale being drawn from a series of calculations based on the above formulæ.

The third of these is at once the most convenient and the most usual, since both the first and second require a computation for each slope that is read.

Considering the First: If the graphical scale for the map has been made to read yards, it is but necessary to scale the distance between the contours at the point to be read and deduce the slope from the above formula, $S^\circ = \frac{19.1 \times V.I.}{M.D.}$.

Example: The scaled distance between the

825 and the 850 contours is 239 yards. What is the slope? V. I. = 850 − 825 = 25 feet. M. D. = 239 yards. $S° = \frac{19.1 \times 25}{239} = 2°$.

The scale of M. D.s may also be made by the use of the scale of yards, for suppose the V. I. of the map is 20 feet, then the formula $\frac{19.1 \times V.I.}{S°}$ becomes $\frac{19.1 \times 20 \text{ feet}}{S°}$, and for a 1° slope $\frac{19.1 \times 20}{1}$, which is equal to $\frac{382}{1}$; so that we may lay off on a strip of paper 382 yards, using the scale of yards, and mark it 1°, that being the distance apart of 20-foot contours on a 1° slope. A 2° slope would be one-half as long (= 191 yards), a 3° slope one-third as long (= 127 yards), etc.

Second Method: In this method the R. F. of the scale must be considered—no scale of yards having been made—for we wish to find the slope where contours *at the scale of the map* are a certain distance apart. This will be best understood if we first work out the scale of M. D.s by this method. The problem is exactly the same as that considered on page 23 under the subject of "Scales." There we learned that to find the

number of inches which would represent a certain unit (yards were the units sought), it was necessary to first divide the number of inches represented by 1 inch on the map by the number of inches in the unit, the result being the number of units (yards) shown by 1 inch on the map. In the present problem the unit, instead of being yards, is the base of a triangle whose altitude is the V. I. of the map. Suppose the R. F. $= \frac{1}{21120}$ and the V. I. $=$ 20 feet. Then from the triangle of reference we know that for a slope of 1° the M. D. will be 20×57.3 feet $= 1,146$ feet, which is equal to $1,146 \times 12$, or 13,752 inches, so that our unit of measure is 13,752 inches, and by the rule [(*a*), page 23] 1 inch will represent $\frac{21120}{13752} =$ 1.54 of such units, and by the rule [(*b*) page 23] 1 such unit will be represented by $\frac{1}{1.54} = 0.65$ inches. A 2° slope will be half as long (0.325 inch), and a 3° slope 0.22 inch, etc. This may all be expressed by the formula M. D. $= \frac{\text{V.I.} \times 12 \times 57.3}{\text{S}^\circ \times \text{Denom. R.F}}$, and so long as the 12 and the 57.3 of the formula remain constant, which will

be the case when the V. I. is given in feet, we may simplify the formula by writing it M. D. = $\frac{\text{V.I. x 687.6}}{\text{S}^\circ \text{ x Denom. R.F.}}$, or, considering 687.6 as 688, M. D. = $\frac{\text{V.I. x 688}}{\text{S}^\circ \text{ x Denom. R.F.}}$

In the example just worked out the values become $\frac{20 \times 688}{1 \times 21120} = \frac{13760}{21120} = 0.65$ inch, as before. But the reverse of the above will occur in map-reading where the degree of slope is unknown and the M. D. is known, and in such case the formula will become $\text{S}^\circ = \frac{\text{V.I. x 688}}{\text{M.D. x Denom. R.F.}}$; *e. g.*, $\frac{20 \times 688}{.65 \times 21120} = 1^\circ$.

If, then, in examining a map we find the R. F. = $\frac{1}{25000}$ and the distance apart of two adjacent contours (825 and 850) to be 0.23 inch, the slope will be $\frac{25 \times 688}{.23 \times 25000} = 3^\circ$.

Rule.—Multiply the vertical interval between contours in feet by 688 and divide this result by the measured distance between contours in inches by the denominator of the R. F. The result will be the slope in degrees.

The scale of M. D.s can also be constructed graphically, with sufficient accuracy for military purposes, as follows:

Draw two parallel lines distant apart 10 times the V. I. at the scale of the map, and on the lower line construct a triangle as ABC, Plate 13, making the altitude BC = 1 inch and the base AB = 5.73 inches.

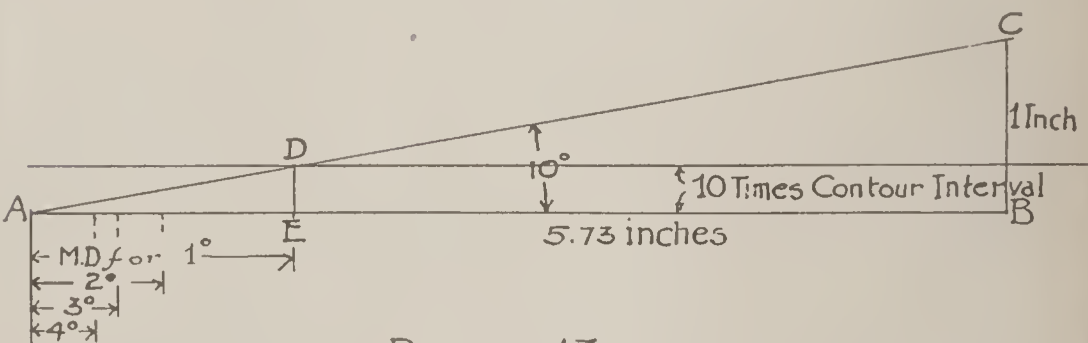


PLATE 13

From the triangle of reference we know that the angle at A = 10°, for the base is $\frac{1}{10}$ of the length of a base corresponding to a slope of 1° and a rise of 1 inch. Since we have drawn the contour interval (D.E.) ten times too large and an angle of 10°, whose base is $\frac{1}{10}$ as long as an angle of 1°, these two dimensions will neutralize each other and AE, the distance from the point A to the point E directly below the intersection at D will be equal to an M. D. for a 1° slope at the

scale of the map and proper contour interval. A slope of 2° will be shown by one-half this distance, a 3° slope by one-third of the distance AE, etc.

Example: V. I. = 20 feet = $6\frac{2}{3}$ yards. Lay off the parallel lines $10 \times 6\frac{2}{3}$ yards, or $66\frac{2}{3}$ yards apart, using the scale of yards which you have made for the map. Draw the triangle as explained, base 5.73 inches, altitude 1 inch, and from the intersection of the slope with the parallel line drop a perpendicular to the lower parallel line. The M. D. thus found for 1° may be divided as explained under "Scales."

PROBLEMS.

1. The scaled distance between the 1,020 and the 1,040 contours is 127 yards. What is the slope? *Answer:* $\frac{19.1 \times 20}{127} = 3°$.

2. The scaled distance between the 2,500 and the 2,525 contours is 400 yards. What is the slope? *Answer:* 1.2°.

3. The scaled distance from the bottom of

a uniform slope (elevation 1,200) and the top (elevation 1,325) is 795 yards. What is the slope? *Answer:* 3°.

4. The R. F. $= \frac{1}{100000}$; the V. I. = 5 meters, the distance from the 200 to the 205 meter contour is 0.18 inch. What is the slope? *Note:* 1 meter = 3.28 feet.

Answer: It is first necessary to reduce the V. I. to feet; V. I. $= 5 \times 3.28 = 16.4$ feet. The equation then becomes $\frac{16.4 \times 688}{0.18 \times 100000} = .627°$.

Had the value of the meter been given in inches (39.37 inches = 1 meter), this value would have been reduced to feet, or the numerator of the equation would have been written $39.37 \times 5 \times 57.3$, which is clear when we remember how the 688 was obtained.

5. The R. F. $= \frac{1}{25000}$; the V. I. = 20 meters; the distance from the 200 to the 220 meter contour is 1 inch. What is the slope? *Note:* 1 meter = 39.37 inches.

Thus far we have considered slopes only in terms of degrees. In work on roads, railroads, and rivers the inclination of the ground is often,

if not usually, expressed in *gradients*—that is, in the form of a fraction, whose numerator is unity and whose denominator is the horizontal distance *in the same unit of measure* which corresponds to a rise of 1 unit. We know from the triangle of reference that a 1° slope rises 1 foot in a horizontal distance of 57.3 feet. The gradient of a 1° slope is therefore $\frac{1}{57.3}$, which may be called $\frac{1}{60}$, without introducing any appreciable error. A slope of 2° is a gradient of $\frac{1}{30}$, etc., the gradient corresponding to any slope being found by multiplying $\frac{1}{60}$ by the degree of slope, and the slope corresponding to a gradient being found by the reverse process—*i. e.*, multiplying 60 by the gradient; *e. g.*, 5° slope $= \frac{1}{60} \times 5 = \frac{1}{12}$: and $\frac{1}{12} \times 60 = 5°$ slope.

Gradients are written $\frac{1}{12}$, or 1 in 12, or 1:12, and, like the R. F., express a ratio, so that any value may be given to its terms so long as both numerator and denominator are expressed in the same units. A gradient of $\frac{1}{12}$ means a rise of 1 foot in 12 feet, and also a rise of 1 meter in 12 meters, etc.

The use of gradients in map-reading is not, however, confined to questions of roads, railroads, and rivers, for if you scale the distance between the contours and find it to be, say 125 yards (which is equal to 125×3 feet $= 325$ feet), this may become the denominator of a gradient whose numerator is the V. I. of the map. If the V. I. $= 25$ feet, the gradient would be $\frac{25}{325} = \frac{1}{15} = 4°$.

Example: The scaled distance between 20-foot contours is 150 yards. What is the gradient and what the slope? *Answer:* $\frac{1}{22.5} = 2.68°$.

The practical value of slopes and gradients in their relation to the movements of troops may be seen from the following table:

TABLE I.

Influence of Slopes on Movement of Troops and Vehicles.

Slopes up to 5°

Are practicable for all arms. Cavalry will charge more effectually uphill than down. Artillery fire is more effective downhill than up.

Between 5° *and* 10°

Close movements for infantry are difficult. Cavalry can only charge uphill a short distance. Artillery moves with difficulty; its effectual and constant fire ceases. A slope of 8° will almost stop baggage-wagons without extra horses.

Between 10° *and* 15°

Infantry can only move a very short distance in order. Cavalry can only trot a short distance uphill and walk down. Artillery moves with great difficulty; fire ceases entirely.

Between 15° *and* 20°

Infantry cannot move in formed bodies. Cavalry can ascend at a walk and descend obliquely.

Between 20° and 25°

Infantry can only move in extended order; light cavalry can only ascend and descend obliquely, one by one.

Between 25° and 30°

Infantry as before, but very slowly; cavalry as before, but with great difficulty.

Slopes over 30° may be climbed up by men using their hands.

VI.

Visibility.

Of all the problems which arise in map-reading, probably none are so frequent as questions involving visibility. "Can the bridge at A be seen from the hill at B?" "How much of the river can be seen from the top of Prospect Hill?" etc. Such problems involve a knowledge of only so much of map-reading as we have passed over and furnish excellent exercises, and because of their value as map-reading exercises, and because of the grasp of the subject of map-reading that such problems give, practice in these problems is of prime importance, and should not be slighted by the student.

Considering the surface of the ground in very broad terms, it may be said that a general section of the ground (except on a dead-level) must be either convex or concave. If it is convex, one end cannot be seen from the other, while if it

is concave, the ends are mutually visible (Plate 14). Visibility thus turns on whether the general section is convex or concave. Frequently this may be determined by mere inspection, as where the slope is that shown in Plate 14 (*a*) or

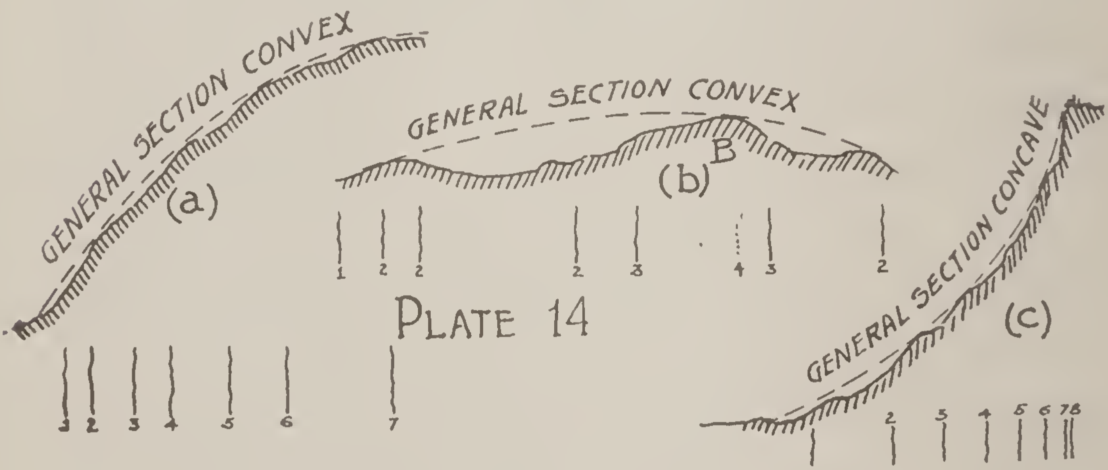


PLATE 14

(*c*). In these cases the contours will lie close together at the bottom of the slope, as in (*a*), when the general section is convex, or close together at the top, as in (*c*), when the general section is concave. When the section is as shown in (*b*), a doubt will arise, which will require a little closer scrutiny, for the point B may be high enough to make the general section convex and it may not. The simple expedient of draw-

ing the section at once suggests itself; for example (Plate 15). Is the bridge at C visible from A? The elevation of B is $2\frac{1}{2}$ contours higher

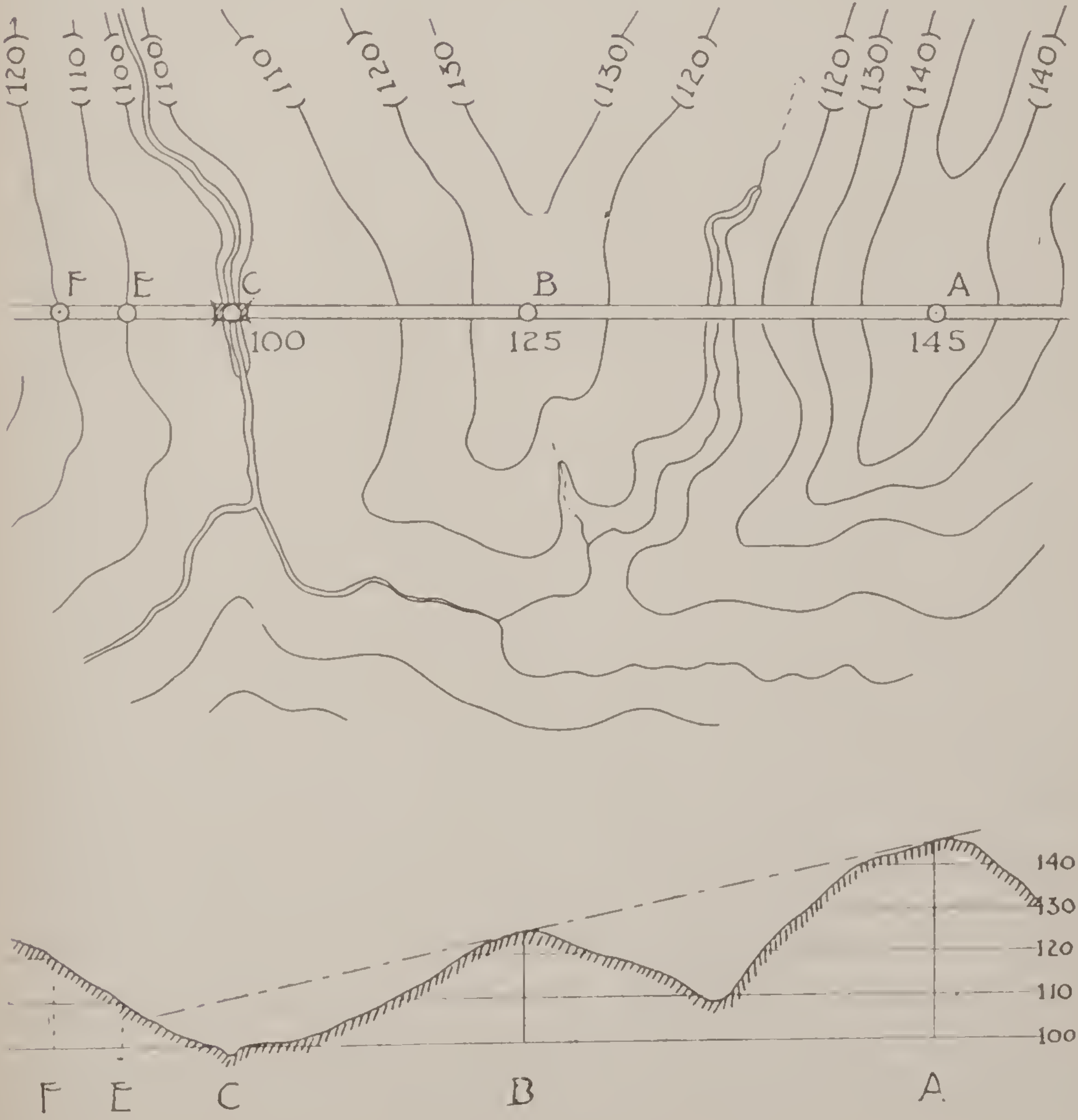


Plate 15

than the bridge and that of A is $4\frac{1}{2}$ contours higher than the bridge. It is unnecessary to reproduce the whole section; the point of observation A, the point to be observed C, and the point of possible interference B, only are involved. Lay the lower edge of a piece of paper along the line A–B–C on the map, and make a pencil-mark opposite the three points A, B, and C. At the B mark erect a perpendicular $2\frac{1}{2}$ units high and at the A mark one $4\frac{1}{2}$ units high, counting from the edge of the paper. Any kind of units will do: an inch scale, the ruling of a piece of foolscap, etc.—in fact, anything that is uniformly spaced. Connect the top of the perpendicular at A with the mark on the edge of the paper at C; if this line crosses the perpendicular drawn at B, C is not visible from A (Plate 16). The same result will be obtained if the section of the line of sight is drawn as indicated by the dotted line (Plate 15), which, starting at the top of the $4\frac{1}{2}$ unit perpendicular (A), just grazes B (top of the $2\frac{1}{2}$ unit perpendicular), and, prolonged, clearly passes above C, which is invisible, since

all below the line of sight would be hidden by the hill at B.

If any other point of possible interference exists similar to that at B, test it as you have at

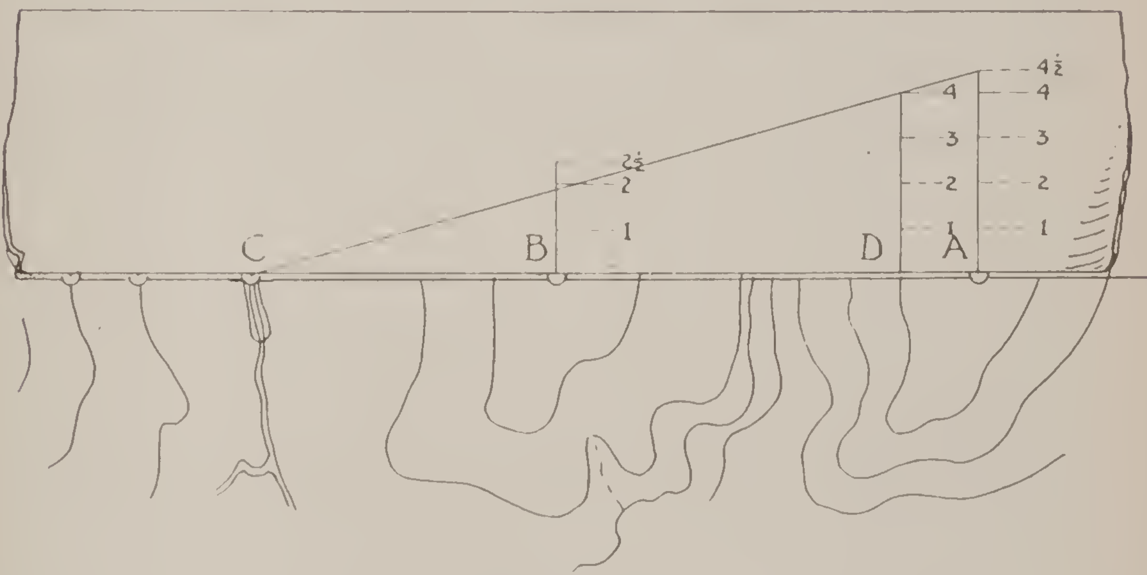


PLATE 16.

B. For instance, the distance from A to the 140 contour indicates a very gentle slope and it may be gentle enough to produce a convex section. The question is solved by marking on the edge of the piece of paper the position of the 140 contour, as at D (Plate 16), and erecting there a perpendicular 4 units high, when it will be seen

that the slope in question is not gentle enough to produce convexity in the general section. All questions as to the visibility of one point from another can be solved in this way. Questions as to the limit of vision—*i. e.*, "point where the line of sight pierces the ground"—are also solved by this method, quickly and accurately.

Referring to Plates 15 *and* 16: We have

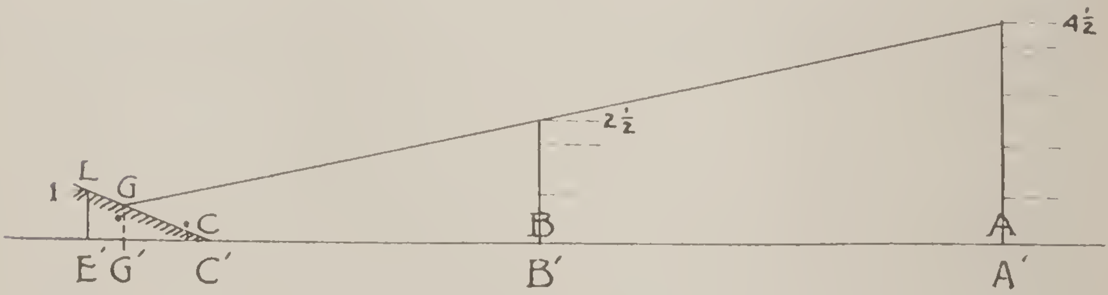


PLATE 17.

seen that a man at C is invisible from A; the question arises as to how much beyond A the man can go and still remain hidden. Lay the paper's edge along the line A–B–C, as before, and mark the position of A, B, and of the crossing of the 100 and 110 contours at C and E as indicated (Plate 17). Erect the perpendiculars

as before—$4\frac{1}{2}$ units high at A, $2\frac{1}{2}$ units high at B, and 1 unit high at E—each corresponding to the number of contour intervals of the respective points above the lowest point. Connect the mark at C with the top of the perpendicular erected at E (thus reproducing the slope at this point); now connect A and B and prolong the line until it intersects the C–E line (at G), and from this intersection drop a perpendicular to the edge of the paper. This will make a new mark on the paper's edge, which, transferred to the map, will show the first element of the slope C–E, which would be visible to an observer at A—"the point where the line of sight pierces the ground."

It is not always convenient nor necessary to solve visibility problems in this manner, and resort is often had to one or another of the several methods of *calculating* the effect of an intermediate point on the line of sight.

One of these methods has for its object the determination of the convexity or concavity of the general section, based on gradients to the in-

tervening object. For example (Plate 15), the distance from A to B is 700 yards; from B to C is 500 yards; the rise in these distances is, respectively, 20 and 25 feet, so that the gradients become $\frac{20}{700}$ and $\frac{25}{500}$. The upper gradient ($\frac{1}{35}$) is gentler than the lower ($\frac{1}{20}$); hence the general section is convex, and C is not visible from A.

Another method, and the one generally employed, is based on the principle of similar triangles. Referring again to Plate 15, if a triangle is formed whose base is the distance from A to B and whose altitude is the difference in elevation between B and A (20 feet), a similar triangle whose base is twice as long will have an altitude twice as great (40 feet) (Plate 18). Now, if we take off on the edge of a piece of paper the distance A–B and then move the paper along the line A–B–C until the A mark is at B, the B mark will be at a point on the map where the line of sight from A and just grazing B will have an elevation 40 feet lower than A, or 105 feet. This new position is beyond C (elevation 100) and is

higher, so that C is below the line of sight and invisible.

Now consider the proposition of an observer at C looking toward A. The map distance C–B is taken as before, and means a rise of 25 feet. Applying this distance toward A, the first ap-

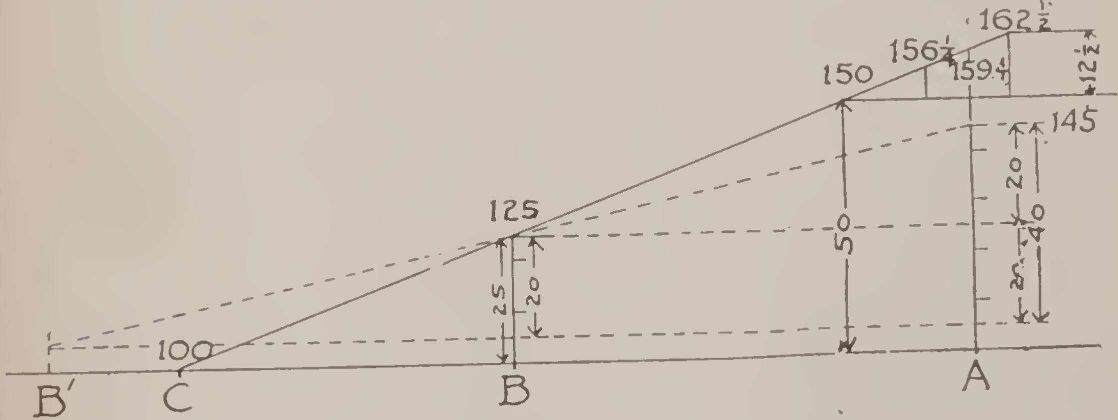


PLATE 18.

plication gives the elevation of the line of sight at its upper end as 150 ($2 \times 25 + 100$). A is only 145, and it is not necessary to go farther to see that A is below the line of sight and invisible.

The question is often framed, however, so as to require a knowledge of exactly how far above the distant object is the line of sight, as where

"The top of a monument at A is just visible to an observer at C. How high is the monument?" Keeping in mind the properties of similar triangles, the question becomes—solving by this method and in extension of what we have already shown—to find the altitude of a similar triangle whose base is the distance from the end of the last application of the original base to A. One-half of the original base will give an altitude of one-half of 25 feet = $12\frac{1}{2}$ feet. Halve the base by folding the marked paper, and try for length. It lies beyond A, and has an elevation of 150 + $12\frac{1}{2}$ = $162\frac{1}{2}$ feet. Halve this distance by again folding the paper (= rise of one-half of $12\frac{1}{2}$ = 6.25 feet). This falls as far short of A as the other fell beyond, and gives an elevation of 150 + 6.25 = 156.25 feet. Again halve this base in the same manner (= a rise of one-half of 6.25 = 3.13), and it falls on A and shows an elevation of the line of sight at A of 156.25 + 3.13 = 159.38 feet. As the ground at A has an elevation of 145, the monument must be equal in

height to the difference between these elevations, or 14.38 feet.

In practice, such repeated halving of the distance is not commonly performed, an estimation of the distance being sufficiently accurate. For example, having made the first application of the base, and found the far end (150) so near A, it would be clear that another whole application of the distance would be too great, and the paper would be folded as explained, so as to halve the base. On trying this new base (whose altitude is $12\frac{1}{2}$), it would be observed that A lies about three-fourths of its length—that is, of the distance from 150 to $162\frac{1}{2}$. It would only be necessary to add to 150 about three-fourths of $12\frac{1}{2}$ ($= 9.375$) to know that at A the elevation of the line of sight is 159.375.

A similar process would show where the line of sight pierces the ground, the folding and refolding of the paper continuing until the ground and the line of sight have the same elevation. It is usually close enough in the latter class of problems to know between what two adjacent

contours the line enters the ground, for the exact spot is of little importance, and the inaccuracies of the map will be greater than the error thus introduced.

The last two methods required the use of paper and pencil; but a scale of equal parts or of yards and a little mental arithmetic will also solve such problems on the principle of similar triangles (their sides, it will be remembered, are proportional), for we can mentally compare their bases. In Plate 15, A is $4\frac{1}{2}$ contours higher than C and B is $2\frac{1}{2}$ contours higher than C—that is to say, the altitude of the triangle at B is $\frac{2\frac{1}{2}}{4\frac{1}{2}}$ of that at A ($=\frac{5}{9}$). For C to be just visible from A it must be at C′ at a distance from B exactly $\frac{5}{9}$ of the whole distance from C to A (Plate 19). The distance is less than $\frac{5}{9}$ and C is invisible. The triangles C′BD and C′AE are similar and their bases are proportioned to their altitudes. C′ is just visible, CB is less than $\frac{5}{9}$ of CA and C is invisible, and C″B is more than $\frac{5}{9}$ of CA and C″ is visible.

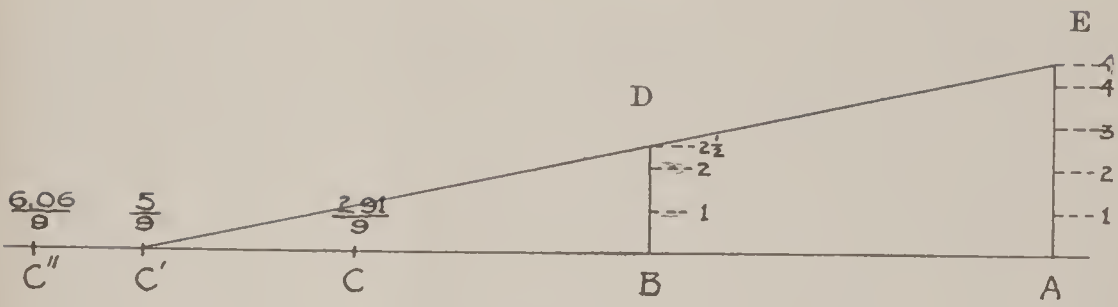


PLATE 19

Or the relations of the triangles may be worked out by the proportion

Distance to intervening object : Distance from observer to observed point :: Partial rise : Whole rise.

Using the figures of the example on page 80 and Plate 18, C to B = 500 yards, C to A = 1,200 yards. The proportion becomes 500 : 1,200 :: 25 feet : 60 feet—that is to say, the line of sight at A will be 60 feet higher than at C, or 160 feet. A being 145 feet, the monument will be 15 feet, as before. The small difference of 0.6 foot is due to the use of different methods, and is immaterial in view of the inaccuracy of maps in general.

Before starting on the next step, it would be well for the student to practice faithfully and persistently the determination of visibility as

outlined here. Imagine yourself at a certain point on the map, preferably on a hilltop at first, and mark the point with a pencil; draw a line in any direction, and examine the contours as they cross it. Can you see the bottom of the slope? How far down the hill would you have to go in order to see the bottom? Would "that" hill prevent you from seeing "that town"? Make up such questions, solve them mentally, and then check your estimate by computation or graphically, as indicated.

In all work of this character it is well to remember that if the observer is at the same height as the intervening object, all lower objects will be hidden, and that often the deciding factor is the contour almost at your feet or just above the object at which you are to look, rather than some prominent feature which looks "like the illustrations in the book." Remember, too, that when looking along a slope contours that lie close together at the bottom and wider apart at the top show a convex general section, which means invisibility; while the reverse conditions

indicate that the top and bottom of the slope are mutually visible. The height of the observer's eye above the ground, the height of trees, houses, and other features shown on the map, and the height of the object viewed, all are ignored in this work, unless the conditions of the problem especially mention them.

The next step is the determination of the area visible from any given point. In solving questions of this character you will use perhaps several of the foregoing methods of determining visibility, but by far the greatest part of the visible area will be determined by inspection alone. The work must be systematically performed, and small refinements of location may be ignored.

Mark your station on the map and from it, as a center, draw a circle of the ordinary visual limits—say two miles. With a pencil, sketch in the limiting borders of all areas that are plainly visible and those that are evidently invisible; this will leave a number of narrow strips that are doubtful. Do this work slowly enough to be reasonably sure of eliminating all

but the doubtful areas. Within these doubtful areas work out on successive lines the point where the line of sight pierces the ground and connect these points. As you grow more expert in map-reading, the areas to be worked out by computation will decrease appreciably, and finally you will be able to solve all ordinary problems with sufficient accuracy for practical purposes by simple inspection.

Questions as to how much of a given stream or road is visible from a given point are solved in the same way, but are more simple than those involving the limits of vision.

The foregoing principles involved in visibility problems will be made clearer by reference to Plate 20 (Map of Fort Leavenworth and Vicinity)* and the following problems, but, before taking them up, a word of caution as to their practical value should be given.

The methods of map-making are such that, with even the most accurate of maps, carefully

*Several small copies of this map accompany the book, that the student may use in solving visibility problems, and thus avoid defacing the larger map.

surveyed in time of peace and made on a fairly large scale, contours will often be found to be incorrectly placed, and many incidents of the ground that are large enough to affect the question of visibility are too small to be shown at the scale of the map, and are therefore omitted. Again, trees, hedges, underbrush, growing crops, etc., exist in nature that are not shown on the map. It is clear, therefore, that where the solution of a visibility problem shows a very small difference between visibility and invisibility—a frequent case in the theoretical problems with which we have been working—no practical reliance could be placed on the result. Yet many practical uses of this class of map-reading problems will arise in actual service, where, allowing a sufficiently large margin for the confessed limitations and inaccuracies of the map, troops may be marched and posted, attacks launched, and patrols and scouts directed, hidden from the sight of the enemy by the topographical features shown on the map and appreciated by a skilful map-reader.

VII.

Problems in Visibility.

Fort Leavenworth Map (*Plate* 20.)

Question 1.—*Can an observer at* B *see the northwest corner of the wall of the Federal Penitentiary at* C?

Answer.—No; he cannot. The hilltop south of B (1,060) intervenes and is high enough to intercept the view. A sketch section, as explained on page 77, will show this at once, and it will be good practice for the student to make one. Meantime, it may be noted that from B to the south edge of the intervening hill is 1.7 inches with a fall of 1 contour, while in the 8.1 inches from that point to C is a fall of $5\frac{1}{2}$ contours (1,060 — 950). The lower slope is the steeper, the section is convex, and C is not visible from B.

By the usually adopted method the same result is obtained, for—taking the distance from B to the 1,060 contour on the edge of a piece of paper—it represents a drop of 20 feet (1,080 — 1,060) in the line of sight. The first application towards C gives an elevation of 1,040—just grazing the 1,040 contour opposite the "S" of "Sheridan's Drive." The next application (= 1,020) is near the word "Cemetery," the next (= 1,000) on "Long Ridge," the next (= 980) at the railroad. Folding the paper brings the first application of the half-base (= 970) on the 860 contour. Another application will evidently go far beyond C, so the paper is again folded, representing a fall of 5 feet. The application of this base (= 965) is beyond C, which point lies about three-fifths of the length of the base (= a fall of 3 feet) beyond the 860 contour. The elevation of the line of sight at C is, therefore, 970 — 3 = 967 feet, and C, with an elevation of 950, is below it and invisible.

It will be observed that the first application of the base (1,040) falls on the 1,040 contour,

showing that a line grazing the ground at the point selected for "the intervening point" also just grazes the ground at the 1,040 contour. A very slight change of either the base or the position of the 1,040 contour would make *this* the intervening feature, and *not* the 1,060 contour selected. The advantage of this method of determining visibility is thus illustrated in that, like the system of drawing a section, the ground may be examined all along the line of sight for possible points of interference, an advantage not possessed by the other methods. It is more convenient than the "section" system, and yet possesses almost the same virtues, and it should now be clear to the student why map-readers prefer this method to others which *seem* easier, such, for instance, as the following:

The intervening feature is 5.5 contours and B is 6.5 contours higher than C; and the distance from C to the intervening feature is *not* $\frac{5.5}{6.5}$ of the distance from B to C. ($\frac{5.5}{6.5}$ of 9.8 inches = 8.3 inches.)

Or, again, the distance from B to the 1,060

contour is 766 yards and from B to C is 4,340 yards. Now, the drop in the first distance is 20 feet, and from the proportion 766 : 4,340 :: 20 : 113.3 it is seen that at C the line of sight would have an elevation 113.3 feet less than B. (1,080 — 113.3 = 966.7.) C is 16.7 feet below the line of sight and is invisible.

It should also be observed that in the solution of this problem the hill south of B was taken as being at and having the elevation of the farthest crossing of the top contour (1,060). This is usually the method of determining the height and location of the intervening point where the location and elevation of the highest point of the hill is not given in figures. It is based on the assumption that the last element of the hill above the top contour has the same slope as the line of sight or that it has a gentler slope. Since neither the height of the observer's eye above the ground nor the size of the object observed is considered, this assumption may safely be made. Whenever, in a problem, this would be evidently untrue, or a closer approxi-

mation to the slope and position of the high ground within the top contour can be made, the usual assumption given here would, of course, stand aside for the better one.

QUESTION 2.—*Can an observer at* B *see the top of the Catholic church steeple at* D?

ANSWER.—Yes. The contours indicate a concave general section, but the hill 880 lies between and quite close to one end of the line of sight, and this is a condition which usually demands consideration because of the marked effect on the line of sight which even a slight rise produces, if that rise occurs near one end of the line of sight.

In this problem the height of D (900) makes it unnecessary to consider the 880 hill, which is clearly below D. Whether the observer at B could see the bottom of the church (855), however, is not so apparent, but by drawing a section or by successive applications of the base from B to the hill 880 it will be seen that the bottom of the church is just visible. The whole base is so large that the

paper is at once folded three times, giving eight divisions, each of which represent a fall of one-eighth of 200 feet = 25 feet. The first application of this base falls on the church with an elevation of 855; or, the rise from the church to the 880 point is 25 feet; from the church to B is 225 feet and the shorter distance is just $\frac{25}{225}$ ($= \frac{1}{9}$) of the whole distance from B to D.

QUESTION 3.—*An outpost has patrols at* 4, 5, *and* 6; *a hostile patrol at* A *observes one of these patrols. Which patrol was seen?*

ANSWER.—The patrol at 5 was seen.

Considering the patrol at 4: To see this patrol, the patrol at A must look over the flat surface along the road included in the 860 contour. This is the same elevation as at A, hence anything on a lower elevation is hidden; 4 is 90 feet lower (770) and is invisible.

Considering the patrol at 5: As before, the 860 contour hides all below it, but 5 is above 860 (it is 890) and may be visible. We ignore everything below 860, and so have nothing to consider except the ground immediately in front

of 5 (above the 860 contour). This has a concave section, and 5 is visible. The patrol at 6 can be dismissed from consideration, as it is below 860.

QUESTION 4.—*An outpost has sentinels at 1, 2, and 3. A hostile patrol, moving from Schueffer's house along the route indicated by the dotted line was first seen as it crossed the Millwood Road. Which sentinels saw the patrol at that point?*

ANSWER.—The sentinel at 3 first saw the patrol. No. 1 could not, for the 1,000 contour of the spur south of Hancock Hill is about halfway to the Millwood Road, where the line of sight would have an elevation, roughly, of 960. ($1,040 - 1,000 = 40$; $2 \times 40 = 80$; $1,040 - 80 = 960$.)

No. 2 cannot see the head of the column. By inspection we see that the same spur is the obstacle, if there is any. A line drawn in the direction of the head of the column and tangent to the spur crosses it at an elevation of 930, 115 feet below No. 2 and 5 inches from him. The remaining distance to the head of the column is

3.2 inches, so the line falls in that distance $\frac{3.2}{5}$ of 115 feet = 73.6 feet. The line then has an elevation of 856.4 feet at the head of the column, and as the head of the column itself at this point has an elevation of only 850, it cannot be seen by the sentinel at No. 2.

No. 3 can see the column, for while it appears that the same spur may interfere, a closer inspection shows that it does not. The line is tangent to it at an elevation of 900 feet, 120 feet below and 6 inches from No. 1. The remaining distance is about 3 inches, at which point the line is $\frac{3}{6}$ of 120 or 60 feet below 900, and has an elevation of 840 feet. The head of the column at 850 feet can be seen by No. 3.

QUESTION 5.—*What point on the north-south road had the column of the preceding problem reached when it was visible to all of the sentinels?*

ANSWER.—Such a problem might, under some circumstances, be very difficult and even indeterminate, but in this case it is not difficult. The obstacle to sight, considered in each case, has been the same spur and it has interfered

with No. 1 more than with the others. If we find a point where this spur no longer prevents No. 1 from seeing the column, it is probable that both of the other sentinels will be able to see it at this same point. If we place the head of the column about .25 inch south of the north branch of the 840 contour on this spur, No. 1 can see it.

Pivot a rule on the observer's station (No. 1) and make it tangent to the nose of the 1,000 contour. In this line the patrol on the road will have an elevation of 870 and be invisible. Tangent to the 980 contour the patrol has reached the stream 860 and is still hidden; tangent to the 960 contour the patrol is at the 940 and is still hidden. For the first time it becomes visible to No. 1 about .25 inch south of the 940 contour. It is also visible to Nos. 2 and 3 at this point, and hence for the first time visible to all.

It will be remembered that in such problems the general rule is that, when the map shows that we can just see or cannot see from one point to another, or where the decision could be

changed by a slight change in the height or form of the contour, no map is sufficiently accurate to allow an important decision to be made on such information. However, many points as to visibility may be safely settled with even a good military *sketch* when it is evident that a considerable difference between the map and the ground would not affect the truth of the decision. The omission from consideration of woods, which is here allowed, would not, of course, be justified in actual practice. Their position and estimated height would have to be considered exactly the same as intervening high ground. If, however ,the trees were scattered, it might be seen that they would not make a perfect screen, and the result might show that if a tree were just in line so that it would interfere with the sight, a movement of a few feet by the observer would enable the distant object to be seen by him.

QUESTION 6.—*How much of the Millwood Road can be seen by an observer standing on the figures* 1,060, 300 *yards N. N. W. of* B?

ANSWER.—It is visible throughout its length.

From the edge of the Military Reservation (dotted N.-S. line) to Salt Creek the observer is looking along a concave slope. From the creek to the hill at Taylor's he is looking over a valley (concave); from Taylor's to the edge of the map is probably visible in the absence of data sufficient to determine the exact slopes on the hilltop.

QUESTION 7.—*What extent of country would be visible to a man standing on Engineer Hill (at* E) *if it* is *assumed that the woods are correctly shown and that they are thick enough to interfere with vision and are of an average height of 40 feet? Consider the observer's eye as 5 feet above the ground.*

ANSWER.—In the solution of such problems the results are obtained largely by the determination of two points on the line of sight—the point of tangency, which we have called the "intervening object," and the point where the line of sight pierces the ground. The first of these usually can be recognized by inspection, the second by the methods previously discussed. The

problem of determining the point of tangency is a little different from the simple case of visibility, heretofore explained, in that, no longer having a definite line connecting two points at the ends, we usually determine the direction of the trial lines of sight by an arbitrary choice of the intervening feature; as where, in determining the area hidden by a spur, we try successive contours, as we did in Problem 5 (*q. v.*).

Under the conditions of this problem the woods are too dense to be seen through, hence, with a blue pencil, we can block out all woods, the ground within the woods being invisible. Stick a pin at E and pivot a ruler on it; move the ruler tangent to the east edge of the woods southwest of the National Cemetery, and draw a line to the E. S. E. Similarly mark the area hidden by the woods on south Merritt Hill to the southwest and east toward the Rock Island bridge. Block out the hidden area. Move the ruler to the west end of the buildings near Kearney Avenue and draw a line northward from the buildings. These buildings will hide everything

behind them, being on high ground. Similarly draw a line tangent to the west and another to the east end of the barracks on Pope Avenue. Follow the south and west faces of the buildings on the West End Parade with a blue pencil, and you can block out as invisible all of the ground hidden by the buildings. Draw a line down the nose of North Merritt Hill from about the middle of the barracks to Grant Avenue at Merritt Lake. The east slope of this hill will be hidden and the valley beyond to about the 840 contour. The 860 contour on Engineer Hill will hide the slopes of that hill and the stream-lines at their bases; Merritt Lake will also be hidden, except the east end; the crest of South Merritt Hill will hide all beyond; similarly, the hilltop 870 will hide what is behind it as far as the slope near Atchison Cross, and the pivoted ruler, just touching this 870 contour, marks the limits of the hidden ground. Where the eastern limiting-line crosses the south slope at the 860 contour the invisible portion spreads to the east in the valley, keeping a little below the 860 contour as

far as the nose, where it joins the invisible area on the northern fork of the stream. The east end of the top of Long Ridge will be visible, also a portion of the garden and apparently a portion of the target-range.

In a general way we may thus block out the greater part of the hidden area, leaving but little to be worked out, such as the boundaries of invisible portions where not wholly apparent, etc.

Considering the doubtful part of the Target-range: The woods southwest of the National Cemetery will hide all behind them as far as the next invisible portion in the woods near the railroad-cut, for the elevation of the lowest trees is 40 feet + 880 = 920 feet, and the line of sight is inclined upward, increasing this elevation rapidly.

Draw the first test-line tangent to the nose of the 900 contour just above the letters "rd" of "garden." From E to this point is a rise of 25 feet; therefore this line, beyond the point of tangency, is higher than 900, and so higher than any

part of the target-range, and the blocked-out portion may be extended to the new line beyond the point of tangency. Draw a similar line tangent to the same spur at the 880 contour (below "ar" of "garden"); this shows a rise of 5 feet (880 — 875) in 2.4 inches, or $\frac{5}{24}$ feet in $\frac{1}{10}$ of an inch. By the scale of $\frac{1}{10}$ inch on the ruler we can count beyond the point of tangency $\frac{5}{24}$ of a foot for each graduation until ground and line of sight are equal.

The falling ground beyond the tangent point shows that the ground is hidden, and allows us to skip from that point to, say about the 4-inch mark. This gives us:

Point.	Elevation of Line of Sight.	Elevation of Ground.
Tangent Pt.	880	880
Tangent Pt. plus 1.6 inches.	883⅓	892 (estimated).

The line of sight is "in the ground" and that point is visible. An examination of the shape of the contours indicates that Long Ridge extends its influence into the target-range, so we select the next point on the line of sight as being at the intersection of the ridge and the test-line with an

elevation of 890 (estimated). This point is 1.3 inches from the 880 contour (point of tangency) and shows an elevation of 882.7, 7.3 feet "in the ground." From here to the crossing of the 880 contour the slope is uniform; at that contour (0.8 inch = 881.7) the line of sight is 1.7 feet above the ground. The exact point of piercing which must occur somewhere in the 0.5 inch between these last two results may be found by the proportion:* 9 : 7.3 :: 0.5 : distance from

*NOTE.—It will be seen that the above proportion is:

$$\left.\begin{array}{c}\text{Distance above ground,}\\ \text{plus distance below the}\\ \text{ground}\end{array}\right\} : \left\{\begin{array}{c}\text{Distance}\\ \text{below the}\\ \text{ground}\end{array}\right\} :: \left\{\begin{array}{c}\text{Horizontal dist.}\\ \text{bet. high and low}\\ \text{ends of line of sight}\end{array}\right\} : \left\{\begin{array}{c}\text{Dist. from}\\ \text{low end of}\\ \text{L. of S.}\end{array}\right.$$

The proportion is also true if the second and fourth terms are given in terms of the *high* end of the line of sight, and so long as the line of sight between both ends lies over a uniform slope. The general proof of this is seen by the following analysis:

Base measures 5 units (0.1 inch each).

Differences of elevation as above are 1.7 feet above the ground at the high end and 7.3 feet below the ground at the low end.

Let X = distance from high end.
Y = distance from low end.

Then X × Y = whole distance = 5 units (1).

X : Y :: 1.7 : 7.3 (2) from similar triangles.

1.7 X = 7.3 Y ......(3) from (2).

$$\left.\begin{array}{l}X = 5 - Y\\ Y = 5 - X\end{array}\right\} \quad \ldots\ldots(4) \text{ from } (1).$$

Substituting value of X as found in (4), the equation (3) becomes:

the 890 point, $= 4.06$ tenths of an inch. The point of piercing, therefore, is about 0.4 of an inch from the 890 point, where the elevation of ground and line of sight is 882. The correctness of this is easily proven, for this point is about 0.9 inch from the point of tangency, and the line of sight therefore has an elevation of $9 \times \frac{5}{24} = 1.9 + 880 = 881.9$. The slope of the ground

$$8.5 - 1.7Y = 7.3Y.$$
$$9Y = 8.5.$$
$$Y = 0.944.$$

Substituting value of Y in (3), as above:

$$1.7X = 36.5 - 7.3X.$$
$$9X = 36.5.$$
$$X = 4.056.$$

This is shown graphically in Plate 22. The triangle *abc* is similar to the opposite triangle *ade* and if transposed so that it occupies the position CB*e*, the comparison of the similar sides is facilitated. BD $= de = 7.3$, BC$= bc = 1.7$, and CD$= 9$. $Y = Y' = Y''$. The base D*a* $= X + Y = 5$ units. From the properties of similar triangles $9 : 7.3 :: 5 : 4.056$ as above, and $9 : 1.7 :: 5 : 0.944$.

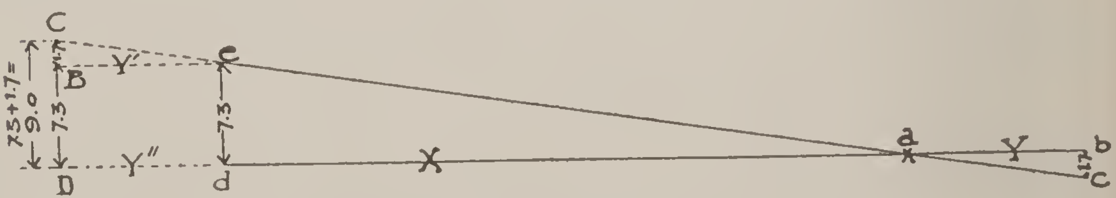


PLATE 22

The exact point of piercing, therefore, lies 0.944 inch from the 880 contour, or 4.056 inch from the 890 point, and its elevation is 881.888. It is hardly necessary to remark that no map would be accurate enough to warrant carrying calculations to this degree of exactness.

shows a fall of 10 feet in 0.5 inch, or 2 feet to 0.1 inch. The point of piercing is about 4.06 tenths from the 890 point and has an elevation of 881.88, the 0.02 of a foot difference being due to coarse measurements.

In a similar manner determine the several points of piercing and connect these; the ground between the line thus found and the line of tangent points is hidden. The point of piercing may thus be calculated; it may be found graphically by drawing a partial section, as explained on page 77 (Plate 17), or in the following manner, using the same example:

The line of sight at the tangent point had an elevation of 880—that is, in 2.4 inches it had risen 5 feet. Prolong the line and lay off this same distance (2.4) beyond the tangent point; this will be a rise of 5 feet more, or 885. From the ridge 890 to the 880 contour the ground falls 10 feet; divide this into two parts, and the point of division will fall where the ground has an elevation of one-half of 10 feet lower than 890, or 885. The mean of these two slopes will be

the point of piercing. To find the mean, divide each into five parts (each part representing 1 foot), and number or letter each. The mean will be where two equal elevations coincide.

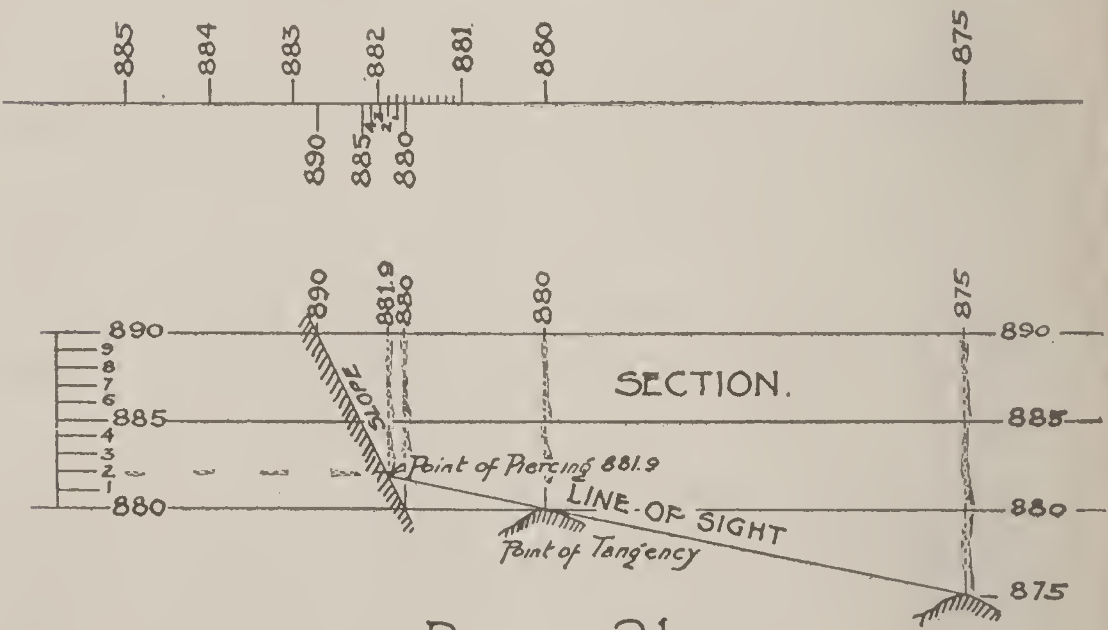


PLATE 21.

(Plate 21.) This work can be done with a light pencil on the map. The elevation (and location) of the point of piercing is thus quickly found, and, as before, it is about 881.9.

QUESTION 8.—*A battery is on the plateau near* H *and wishes to use direct fire against another battery coming into action at* G. *If the muzzles*

of the guns are 3 feet from the ground, how far back from the edge of the plateau can the battery retire and still use direct fire with the maximum of cover? (NOTE.—Consider the ground on the plateau as level between the 1,040 and 1,060 contours.)

ANSWER.—The distance from G (1,020) to the edge of the plateau (1,040) is 1,740 yards (5,220 feet). The inclination of the line of sight is, therefore, 20 feet rise in 5,220 feet, or $\frac{20}{5220} = \frac{1}{261}$. Since the muzzles are 3 feet from the ground, and must lie in the line of sight, they must be 3×261 feet $= 783$ feet from the edge, or 261 yards.

QUESTION 9.—*A blue column has reached Taylor's School-house, marching east on the Millwood Road, when it is fired on by a blue battery on Hancock Hill, which is so posted as to command, with direct fire the road from the school-house to the bridge over Salt Creek. Where is the battery posted? (Consider the top of the hill a plateau between contours, as before.)*

ANSWER.—It is evident that the guns must be near the 1,060 contour to enable them to fire

over the steep slope to the bridge. Assume a position at the fork of the roads and draw lines to the bridge and to the school-house.

Consider the bridge: Fall, 1,060 — 770 = 290 feet in 1,070 yards $= \frac{1}{11}$; therefore the guns will be 11 yards from the 1,060 contour.

Consider the school-house: Fall, 1,060 — 860 = 200 feet in 2,470 yards $= \frac{1}{37.5}$; therefore the guns will be 37.5 yards from the 1,060 contour. The position of the guns may thus be approximated as on the road and near the figures 1,060.

However, we must not exaggerate the importance of these theoretical considerations, for in reality things are not so simple as this. The contours of the ground are not mathematically precise, the slopes are not uniformly regular, and crests are formed of alternate curved and flat surfaces, which completely modify the conditions of defilade. It is, nevertheless, possible to make a rough estimate of what is likely to happen in action and of the points to which executive officers should direct their attention.

With the knowledge of map-reading that you

now possess, you should be able to describe with a certain amount of accuracy the ground that would be seen from any point, the probable character of the roads and of the country passed through in going along the roads. Practice yourself in this by writing road reconnaissance reports, based on the map. A good plan to follow is to assume a march from, say one town to another, choosing your route over the shortest road and the one best suited to wheeled traffic. To do this, draw a line connecting the two towns; now look for the road that diverges least from this line and which has the gentlest grades.* Having chosen your route, begin by

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*Remember that in reducing contours to gradients, both numerator and denominator of the gradient must be in the same unit and that the numerator is always 1. Thus, if the bottom of a hill has an elevation of 800 and the top 920, the rise is 120 feet, and if the distance (measured along the road) is 800 yards, the gradient is $\frac{120}{800 \times 3} = \frac{1}{20} =$ 3° slope.

The inclination of a road is also sometimes referred to in terms of the rise in 100 units, as being "such a per cent" slope or grade. The grade in the example just given would be a 5% grade, since it rises 5 feet in 100 feet ($\frac{1}{20} = \frac{5}{100}$). In that example it will be observed that while the *gradient* is $\frac{1}{20}$, the *grade* is 5% and the *slope* is 3°, all equivalent expressions.

The character of the road is often indicated by the grades that occur on it. A 5° slope ($\frac{1}{12}$) is an excessive grade for a good road, even when crossing the mountains, and it is generally con-

describing the point of starting, then go on to the next point that should be described, state how far it is from the last point, the gradients passed over, the nature of the country, and so on. The following example will illustrate:

Example: It is determined to go from the new U. S. Penitentiary to the Frenchman's. Between Atchison Cross and Salt Creek village you have the choice of two roads: one over the col between Atchison and Government Hills, and the other almost three-quarters of a mile longer, through the railroad cut. The latter

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sidered that $\frac{1}{24}$ is the maximum that should be allowed, and then only for short distances.

A 5% grade ($\frac{1}{20}$) will reduce the tractile power and speed of a horse over that on the level one-half if on a good road, and if this grade is longer than 100 yards, the team must stop to breathe.

The normal load for an Army mule is 1,000 pounds, and this he can haul without difficulty on a hard, level road; on a $\frac{1}{20}$ gradient; this is equal to imposing a load of 2,000 pounds, and since it is about four times as hard to draw a wagon over a dirt road as it is to draw the same wagon over macadam, his load will be equivalent on such a road to 8,000 pounds, if the gradient is $\frac{1}{20}$. A horse is very near his limit of power if drawing 2,000 pounds under favorable circumstances of road-bed and grade; hence, on the hill and road just discussed the teams would have to be doubled if the hill is at all long, and this means a serious loss of time to the train.

Gradients are of the greatest importance when the wagon is ascending the hill, but it is well to remember that on a turnpike road $\frac{1}{35}$ is the greatest slope that will allow horses to trot *down* rapidly and with safety.

has very gentle grades except near the cut, where a short gradient of $\frac{1}{6}$ must be ascended $(\frac{60}{120 \times 3} = \frac{60}{360} = \frac{1}{6})$. The grade to be ascended in the former is longer, but is only $\frac{1}{21}$, or about $3°$ $(\frac{80}{560 \times 3} = \frac{80}{1680} = \frac{1}{21}; \frac{60}{21} = 3°)$, and the shorter road is chosen.

Starting at the northeast corner of the new U. S. Penitentiary—

(1) Cross-roads; N. *via* National Cemetery (2,000 yards) to Fort Leavenworth; S. E. *via* Grant Avenue (1,500 yards) to Leavenworth; W. to Salt Creek village, 1.9 miles. (Route taken.) Surrounding country open and gently rolling; Corral Creek, flowing east, 550 yards N.; buildings in Post ($1\frac{1}{2}$ miles) visible; new U. S. Penitentiary brick walls, 40 feet high, about 250 yards square.

(2) Atchison Cross; distance from (1) 1,200 yards; road from (1) to (2) rises $\frac{1}{9}$ for first 30 yards, then falls $\frac{1}{90}$ for 600 yards, then is level for 250 yards, where spur track from U. P. Railroad to Penitentiary

is crossed, it then ascends $\frac{1}{38}$ for 250 yards, crossing the A., T. & S. F. Railroad; the last 70 yards has a gradient of $\frac{1}{10}$.

The road is everywhere commanded by Long Ridge, 1,100 yards north of and parallel to road.

Cross-roads; S. 1,100 yards to Metropolitan Avenue; N. to target-range and 1,400 yards to road through railroad cut to Salt Creek; 2,200 yards to National Cemetery, and 2 miles to Post; N. N. W. 1,700 yards to Salt Creek. (Route taken.)

(3) Col, 650 yards north of Government Hill, distant from (2) 860 yards; road from (2) to (3) rises 400 yards at $\frac{1}{30}$, then for 230 yards at $\frac{1}{17}$, next 150 yards at $\frac{1}{23}$, last 60 yards nearly level; ground within Reservation hidden by trees except narrow strip in prolongation of road; Salt Creek valley visible from Missouri River to Frenchman's, except about 1,200 yards hidden by Sentinel Hill (elevation 1,020),

a heavily wooded narrow hill, distant N. N. W. about 1,000–1,500 yards; etc., etc.

The above is sufficient, perhaps, to show how the map should be studied. The chief point to be remembered is to try and imagine that you are actually going along the road and making a reconnaissance report on it.

Placing Troops on the Map.

There is one other use of a map indoors that should be understood. In map problems and in some special reports you will be required to indicate on the map the exact location of certain troops and in this there are two common errors that the student should learn to avoid. The first is occupying more room laterally than the given body of troops would actually occupy, or the reverse condition: showing them as occupying a smaller space than they would actually cover. The second is drawing them so timidly and unobtrusively that they are perceptible only after diligent search.

In placing troops, then, always draw them to scale, avoiding the errors of over-extension and of under-extension, and make the block representing the troops thick enough in the direc-

PLATE 23.

tion of depth to be clearly seen. Draw your own troops in bright blue, hostile troops in bright red, and, in the same colors, write clearly opposite each body the designation of the troops which it represents, as "III. / 54" for "Third Battalion, 54th Infantry." (The shape

of the block will show whether infantry, cavalry, or artillery.) Use Roman figures for battalions, squadrons, corps, and armies, and use Arabic figures for regiments, brigades, and divisions. (Plate 23, and Fort Leavenworth Map, Plate 20.)*

EXAMPLES.

III. / 15 (to represent the second squadron of the 15th Cavalry, the second battalion of the 15th Infantry, or the second battalion of the 15th Artillery—according to the shape of the block).

II. Corps (or simply II. in large letters, where no misunderstanding will result).

34 — II. (to represent the 34th $\left\{\begin{matrix}\text{Cavalry,}\\ \text{Infantry,}\\ \text{Artillery.}\end{matrix}\right\}$ less the second battalion—*i. e.*, the first and second battalions of the 54th $\left\{\begin{matrix}\text{Cavalry,}\\ \text{Infantry,}\\ \text{Artillery.}\end{matrix}\right\}$

*The troops are shown on the map as prescribed in par. 331 I. D. R., '04, and illustrate the method of placing troops on a map. No tactical deductions should be drawn from their arrangement.

2 Brig.
3 Div.
2 Div., III. Corps, etc., etc.*

Practice in placing troops on the map is valuable in that you will soon be able to estimate by eye the extent of front occupied by a deployed battalion, squadron, regiment, etc., and the length of the several units stretched out on a road. This facility is of great practical value in map maneuvers and in actual service.

*The abbreviations used are definite and cannot be misunderstood. Lack of space on a map, together with the necessity of using large figures and letters, compels the use of these abbreviations, rather than those used and appropriate for orders and messages

VIII.

MAP-READING IN THE FIELD.

MAP-READING in the field is not essentially different from the same thing indoors. It consists chiefly in ability to orient the map, to find one's place on the map, to recognize features shown on the map, and in an ability to use the map as a guide when traveling in unknown country. These and the problems already discussed constitute map-reading in the field.

Orienting the Map.—The direction or bearing of one line from another must be determined and expressed with reference to some other direction-line, and the reference-line on maps is a north-and-south line, called the "meridian"; but there are two meridians or north-and-south lines at almost every place on the earth: one, the true meridian, which is unvarying, lying always in the same direction and joining the

place with the North Pole; the other, called the "magnetic meridian," joins the place with the magnetic pole. These two lines may differ very widely and in Alaska *do* differ by as much as 40°. The existence of these two reference-lines causes some confusion in map-reading in the field, since maps are drawn sometimes with reference only to one and again with reference only to the other. A military sketch made with a compass will have it on a magnetic meridian, which may "point" in quite a different direction from the meridian found on a survey of the same piece of ground.

The needle of the compass always points to the magnetic north, so that in so far as its limited length permits it establishes a visible portion of the magnetic meridian at the place, and we can therefore, with its aid, actually see the magnetic meridian and measure from it the bearings of the various objects shown on the map. We cannot, however, see the true meridian so easily, and hence, on the ground, we are driven to use the convenient compass and needle. In those

few favored places where the true and the magnetic meridians are identical this will make no difference, for the needle will then point to the true north and we can *see* the true and unchanging meridian; but in the vast majority of cases the needle will point to one north, the meridian on the map to another, and the result is the confusion referred to.

Now, the North Pole is fixed and immovable, but the magnetic pole wanders about, carrying with it the north ends of all the magnetic needles throughout the world; it moves, however, so slowly and with such regularity that map-makers can compute its position for any given date and place, or, by establishing a true north-and-south line by astronomical observations, can compare it with the position of the needle at any time for that place. Maps, for convenience, are usually made with the magnetic meridian; the true meridian's position with reference to the magnetic is determined, the true meridian drawn and the magnetic meridian erased, thus leaving a direction-line on the map that will not

change with the passing years. The user of the map, wishing to read the map on the ground, and with the aid of a compass, does so through a knowledge of the relative positions of the two meridians—the one that he can see on the compass and the one given on the map—for the date and place when the map is to be used.

The magnetic meridian may lie either to the east or to the west of the true meridian and its angular distance from that meridian is called the "variation of the compass," the "declination of the needle," and also the "magnetic declination." In 1908 the variation in the eastern part of Maine is 21° west, in the western part of Alaska it is 40° east. An officer in Maine, having a U. S. Geological Survey map (whose vertical side lines are true north and south) would set the N. S. line of his compass-box on the N. S. border line of the map and revolve map and box together until the needle pointed to 21° west of the true meridian (Plate 24, *a*); while, were he in Alaska, he would turn map and box until the needle pointed to 40° east of the true meridian

(Plate 24, *b*).* In these positions the maps would be "oriented"; the east on the map would be toward the real east, and everything

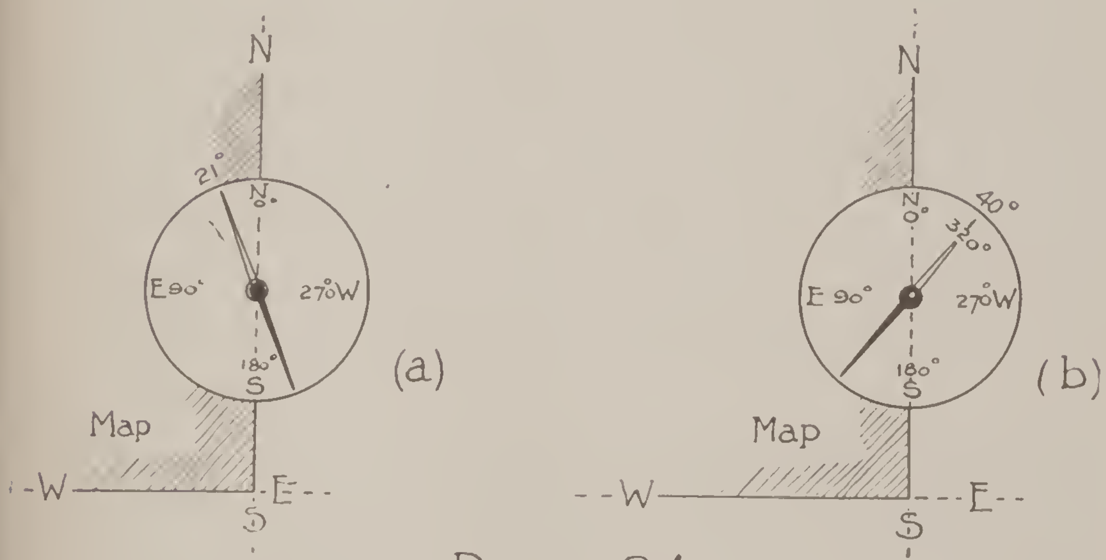

PLATE 24

shown on the map would lie in its proper relation to the same features on the ground. If the map were placed in a straight road and oriented, the plotted direction of the road would coincide with the actual direction, and one looking along the mapped road would see the true road as

*Do not allow the reversed marking of the cardinal points on the compass circle to confuse you in this. Have the needle pointing to the actual E. or W. of the true meridian as indicated in Plate 24, (*a*) and (*b*).

though it were a continuation of that shown on the map. If the map has a magnetic meridian on it, it is oriented at once and without difficulty by adjusting the N. S. line of the compass-box to this meridian and turning map and box until the needle lies at the north point or zero; but if the map has only a true meridian, it will be necessary to find the declination before it safely can be used in the field. In sketching and in map-making this declination must be ascertained with some accuracy, but in map-reading it will be sufficient if you can determine it with only a fair degree of accuracy. This can be done if you stand in some clearly identified stretch of straight road and turn the map until its plotted position coincides with the road in which you are standing. The map will then be oriented, and, placing the N. S. line of your compass on the true meridian, you can read at the north end of the needle the declination for that place and date. A magnetic meridian drawn from the information thus obtained will enable you to orient the map at any other place

in the vicinity in the manner above directed for a map which has a magnetic meridian. If you can identify your position on the map—as, for example, where you are standing at a cross-roads, which is shown on the map—you may orient the map by turning it until some other easily identified place, such as a prominent hill, a church, etc., that is shown on the map, lies in the same direction on both map and ground. With the map oriented, determine the declination as directed.

Identifying One's Place on the Map.—Usually this is easily done by estimating or measuring the actual distance and direction to some easily identified feature shown on the map and then plotting the distance in the reverse direction from the plotted feature; but it may be necessary to resort to a rough application of a plane-table method of resection. Orient the map, draw pencil-lines from the representation of two visible plotted points towards you; their intersection will be at the point where you are standing. Any application of the "three-point prob-

lem" also may be used, but in practice the map is oriented and your position identified without resort to any more intricate methods than those above given. If you have been following along a known road, your position on it can be found approximately from a knowledge of your rate of march by measuring along the road the distance that you estimate you have traveled in the time that has elapsed since you last occupied a known position. Thus, if marching with an infantry column, you left a certain town at 2:00 p. m., you would measure from that town, along the road traveled, $2\frac{1}{2}$ miles (or 3 miles, according to your rate of march), to find your position at 3:00 p. m.

When it is necessary quickly to orient the map and to identify on it the relation between your position and some distant object, take up the map in both hands, the thumb of one hand on your position, the thumb of the other on the distant point, and turn around until the imaginary line connecting your thumbs coincides with

an imaginary line connecting the two points on the ground.

When using the map in close country, you will not be able to see far enough to enable you readily to recognize your position, and, though you have a good map and a compass, it will be astonishingly easy to lose your way unless you are intent upon the relations of map and ground. In such a case, or in a dense forest or jungle, keep your map in hand and approximately oriented. Mark your progress from time to time with a pencil, checking off recognized points as you pass them; keep your eye on the sun or on your compass, roughly checking distances as you progress and checking off all road-crossings and forks, and, if you are the guide of a party, *rely on your own judgment rather than heed the advice that will be offered when the route appears doubtful.* Remember that maps are seldom up to date or complete, and look out for alterations in roads, houses, bridges, etc.

Always carry your map so that it comes out of your pocket ready for use—*i. e.*, with the

printed matter outside and with the part of the country on which you are working before your eyes as soon as you take it out of your pocket. A transparent waterproof envelope or cover for the map is a good thing to have, and it is well to prepare it with squares lightly ruled, the sides of the squares representing a certain number of yards on the scale of the map.

Make sure that you have the scale of the map well fixed in your head, and have some rapid method of measuring distances on the map.* If the map is one with only a true meridian on it, be sure that you know how it is drawn with respect to the points of the compass.

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*Everyone should know the size of some portion of his hand—from one line to another, the length of a finger-joint, of the span from the thumb to little finger, etc. A good measurement to know is the width of the hand at the knuckles, so that the hand, placed palm down on the map, will cover a known number of yards or miles, at say 3 inches to the mile, as well as the number of inches so covered.

IX.

Additional Problems in Map-Reading.

1. Find the R. F. of the following scales:

   5 inches to the mile;
   5 miles to the inch;
   3 inches to 2,000 yards;
   4 inches to 2,000 meters. (1 meter = 39.37 inches.)

2. How many inches to the mile in the following scales?

$\frac{1}{15840}$ $\frac{1}{100000}$ $\frac{1}{80000}$

3. How many miles to the inch in the following scales?

$\frac{1}{63360}$ $\frac{1}{126720}$ $\frac{1}{316800}$

4. You have a map which you are comparing with the ground; the scale has been torn off the map, and in order to draw a scale for it you have paced the distance between two objects, which are shown on the map as 2.75 inches

apart, and which, from your pacing, you find to be 550 yards. Draw the scale of yards.

5. Construct a scale of yards with R. F. = $\frac{1}{10560}$.

6. On a Russian map of Turkestan, of which the scale is 4.75 inches to 500 versts, it is found that the distance from Kizil Arvat to Askhabad is 1.93 inches. What is the actual distance apart of these places in miles? 1 verst = 1,166.6 yards. Give the R. F. of the map.

7. A line $2\frac{1}{2}$ inches long on a French map is marked 2,000 meters. Using the graphical method, draw a scale of yards for use with this map.

PROBLEMS ON U. S. GEOLOGICAL SURVEY MAP.

Standisfield (Mass.) Sheet.

8. Construct a scale of yards for use with this map.

9. What is the direction from New Boston to the following places?

Cold Spring, Tolland, Simon Pond, Southfield, Montville.

10. What is the distance from New Boston to Otis by the most direct road?

11. Your compass has only degrees marked on it; sighting from Montville to Standisfield, the needle reads "236°." What is the bearing in "points"?

12. From New Boston you are ordered to "the hill 1 mile N. E. of this point." Using the above compass, what would be the bearing in degrees of the hill to which you are to go?

13. What is the elevation of the fork in the roads at Standisfield?

14. What is the difference in elevation between Standisfield and Montville?

15. Going from South Standisfield to Southfield, what is the elevation of each of the houses passed?

16. In going from South Standisfield to New Marlboro, what is the slope between the 1,580

and 1,600 contours where you first cross them?

(*a*) Using scale of yards;

(*b*) Using scale of inches.

17. Construct a scale of M. D.s for use with this map.

18. A rise of 200 feet is encountered in a map distance of ½ mile. What is the slope and what is the gradient?

19. Can cavalry charge down the road running north from Standisfield?

20. Is the general section from Standisfield to Montville convex or concave?

21. Is Montville visible from Standisfield?

22. If you were standing on Seymour Mountain, could you see Abbey Hill?

23. Is Cranberry Pond visible from Tolland?

24. Is Otis visible from North Otis?

25. Are both hilltops of Cowles Hill visible from Standisfield?

26. Standing on the west top of Cowles Hill

and looking north, could you see the north fork of Buck River? What point on the hill beyond the river would first be visible?

27. How much of Sandy Brook could you see from the same point?

28. Show a regiment of infantry deployed in one line facing N. E. on the hill between South Standisfield and New Marlboro.

29. Show a regiment of infantry marching on this road, the head of the regiment at the cross-roads north of Woodruff Mountain.

30. Show a brigade (F. S. R.), complete with trains, marching from West New Boston to Otis, the leading element 1 mile south of Otis.

31. Orient the Standisfield sheet for map-reading purposes indoors, using the compass.

32. Orient the map by the border lines if the declination is $6\frac{1}{2}°$ W.

33. Orient the map, considering the declination $20°$ E.

34. Set the map with the top in a general north direction, as though you had oriented it

by a road or other feature on the ground, and determine the declination.

35. Choose your road and make a road reconnaissance report of the route from East Otis to New Boston.

36. Marching $2\frac{1}{2}$ miles per hour, how long would it take to march from North Colebrook to New Marlboro. How long after starting would you pass South Standisfield?

37. What portion of the road from North Colebrook to Standisfield would be under artillery fire from a battery on Seymour Mountain?

38. What is the angle of depression from the east top of Cowles Hill to Standisfield?

39. On what hill within 1 mile of West New Boston would you place an observer to best observe the country in the vicinity of South Standisfield?

40. Where is the steepest grade on the road from Otis to West Otis and what is the grade at that point?

APPENDIX I.

Topographical Terms and Abbreviations Thereof Found in French and German Maps.

German.	French.	English.
Abbau.	Annexe de village.	Farm-house some distance from a village.
Abdeckerei.	Équarrisage.	Place for skinning dead animals.
Brauerei.	Brasserie.	Brewery.
Bruch.	Faille, bas fond marécageux.	Moor, marsh, bog.
Busch.	Bois, bouquet d'arbres, buisson.	Bush, thicket, copse.
Damm.	Digue.	Dike, dam.
Denkmal.	Monument commémoratif.	Monument, memorial.
Dratseilbrücke.	Pont suspendu, (par câbles de fil de fer).	Wire rope suspension bridge.
Eisenquelle.	Source ferrugineuse.	Mineral spring.
Fähre.	Bac.	Ferry.

TOPOGRAPHICAL TERMS—CONTINUED.

GERMAN.	FRENCH.	ENGLISH.
Fährhaus.	Station du bac.	Ferry-house.
Fliess.	Ru, petit canal, fossé.	Small brook, rivuulet.
Forst.	Forét domaniale, grande forét.	Regularly planted forests (governmental).
Furt.	Gué.	Ford.
Gas Anstalt.	Usine à gaz.	Gas-works.
Heide.	Lande, bruyères.	Heather, moor.
Hochofen.	Haut fourneau.	Blast furnace.
Kreuz.	Croix, calvaire	Cross, wayside shrine.
Kriegsstrasse.	Route militaire.	Military road.
Leimfabrik.	Fabrique de colle forte.	Glue factory.
Luch.	Bas fond marécageux.	Swampy bottom. land.
Luftschacht.	Puits de ventilation.	Air-shaft, ventilating-shaft.
Massengrab.	Tombe collective (de champ de bataille).	Burial-trench (on the battle-field).

TOPOGRAPHICAL TERMS—CONTINUED.

GERMAN.	FRENCH.	ENGLISH.
Rangierbahnhof.	Gare de triage.	Switching station.
Revier.	District forestier, verderie.	Forest district, verderer's district.
Schiesstand.	Stand.	Firing-stand.
Seilbahn.	Chemin de fer funiculaire.	Cable road.
Springgrube.	Fossé (pour les exercises de sauts).	Ditch for (jumping exercises).
Stift.	Institution religeuse.	Religious institution.
Uebungsschanze.	Retrenchment d'exercises.	Intrenchment for training purposes.
Viehtrift.	Pâturage.	Pasture.
Wasserleitung.	Aqueduc.	Aqueduct.
Wehr.	Barrage.	Weir, dam.
Zollamt.	Douane.	Custom-house.

ABBREVIATIONS.

German.	French.	English.
B., Bach.	Ruisseau.	Brook, creek.
B., Berg.	Montagne, hauteur.	Mountain, height
Baumsch., Baumschule.	Pépinière.	Nursery for young trees.
Begr., Pl., Begräbnissplatz.	Lieu d'inhumation, cimetière.	Place of interment, cemetery.
Bhf., Bahnhof.	Gare.	Railroad station.
B. W. N., Bahn Wärter, No.	Maison de garde barrière, No.	Crossing-keeper's. hut, No.
Ch. W., Chaussee Wärter.	Maison de cantonnier.	Roadworker's hut.
Fab. or Fb., Fabrik.	Fabrique.	Factory.
F. H., Forst Haus, Försterhaus.	Maison forestière.	Forester's house.
Fl., Fluss.	Rivière.	River.
Fl. Br., Fliegende Brücke.	Pont volant.	Flying bridge.
F. P. M., Friedens Pulver Magazin.	Magazin à poudre de chasse.	Magazine for hunting powder.
G., Gb., Gebirg.	Montagnes.	Mountain.
Gr., Graben.	Ru, fossé.	Channel, ditch.

ABBREVIATIONS—CONTINUED.

GERMAN.	FRENCH.	ENGLISH.
Gr., Gräber.	Tombes.	Graves.
Gr., Grube.	Fossé carrière.	Trench, pit, hole.
Gr., Grund.	Bas-fond, fond.	Ground, low-lying ground.
H , Höhe.	Hauteur.	Height.
Hgl., Hügel.	Colline.	Hill.
H. St., Halte Stelle.	Halte, station de chemin de fer.	Stopping-place.
I., Insel.	Ile.	Island.
Kap., Kapelle.	Chapelle.	Chapel.
K. F., Kahn Fähre.	Bac.	Boat ferry.
Khf., Kirchhof.	Cimetière.	Church-yard, cemetery.
K. P. M., Kriegs Pulver Magazin.	Poudrière militaire.	Military powder magazine.
Kr., Krug.	Auberge.	Tavern.
K. O., Kalkofen.	Four à chaux.	Lime-kiln.
Ksgr., Kiesgrube.	Carrière de gravier.	Gravel-pit.
Ks. u. s. Gr., Kies und Sand Grube.	Carrière de gravier et de sable.	Gravel- and sand-pit.

ABBREVIATIONS—CONTINUED.

GERMAN.	FRENCH.	ENGLISH.
Lgr., Lehmgrube	Carrière de glaise.	Clay-pit.
L. M., Loh Mühle.	Tannerie.	Tan-mill, tannery.
L. u. Mgl. Gr., Lehm und Mergel Grube.	Carrière de glaise et de marne.	Clay- and marl- (slate) pit.
M., Mühle.	Moulin.	Mill.
Obst. Pl., Obst Plantation.	Verger.	Orchard.
O. M., Ol Mühle.	Moulin à huile	Oil-mill.
Pf., Pfuhl.	Mare.	Pool, pond.
P. M., Papier Mühle.	Papeterie.	Paper-mill.
Pv. M., Pulver Mühle.	Poudrerie	Powder-mill.
S., See.	Lac, étang.	Lake.
Schäf. or Schf., Schäferei.	Bergerie.	Sheep-fold.
Schl., Schleuse.	Ecluse.	Sluice, lock.
Schl., Schloss.	Château.	Castle.
Sgr., Sandgrube	Carrière de sable.	Sand-pit.
S. M., Säge Mühle.	Scierie.	Saw-mill.
St. Br.. Steinbruch.	Carrière de pierre.	Stone quarry.

ABBREVIATIONS—CONTINUED.

GERMAN.	FRENCH.	ENGLISH.
T., Teich.	Etang.	Pond.
Thon Gr., Thon Grube.	Carrière d'argile.	Clay-pit.
T. O., Teer Ofen.	Usine à goudron.	Tar works.
Vw., Vorwerk.	Ferme.	Farm-house some distance from a village.
W., Wald.	Forét.	Forest.
Wasch., Waschhaus.	Lavoir.	Laundry, wash-house.
Wein B., Weinberg.	Vignoble.	Vineyard.
W. M., Walkmühle.	Foulerie.	Fullery, cloth-mill.
Wn., Wiesen.	Prairies.	Meadows.
Z. F. B., Zucker Fabrik.	Sucrerie.	Sugar factory.
Zgl., Ziegelei.	Briqueterie, tuilerie	Brick-yard.

APPENDIX II.

Table of the Chief Foreign Measures of Length and Their Corresponding Distance in Inches, Feet, and Miles.

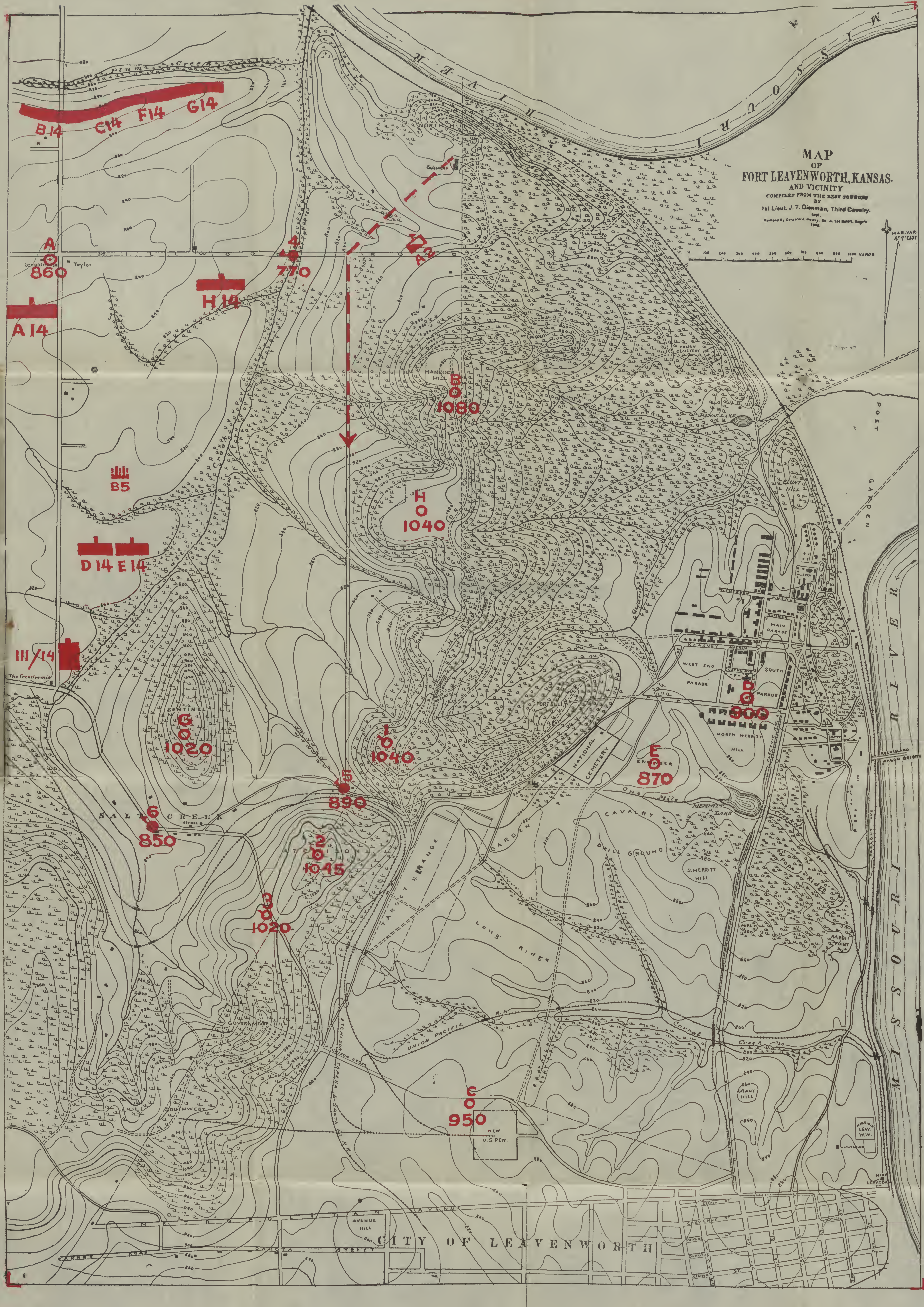
			Inches.	Feet.	Miles.
Metric System.	France, Belgium, Italy, Portugal, Spain,	Millimetre = $\frac{1}{1000}$ metre	.39371	.....	.....
		Metre	.....	3.2809	.....
		Kilometre = 1,000 metres	.....	.....	.62138
	Germany,	Millimeter or strich		Roughly 10 meters = 11 yards, and 1 kilometer = $\frac{5}{8}$ of a mile.	
		Meter or stab			
		Kilometer			
	Greece,	Gramme = millimeter			
		Pecheus = meter			
		Stadion = kilometer			
	Holland,	Streep = millimeter			
		El = meter			
		Mijle = kilometer			
	Austria,	Linie	.0864	.....	.....
		Fuss = 144 linien	.....	1.0371	.....
		Meile = 24,000 fuss	.....	.....	4.7142
	China,	Ts'un (10 fan)	1.41	.....	.....
		Ch'ih (10 ts'un)	.....	1.175	.....
		Li	.....	.....	.4005
	Denmark and Norway,	Linie	.0858	.....	.....
		Fod = 144 linien	.....	1.0297	.....
		Mil = 24,000 fod	.....	.....	4.6805
	Japan,	Bu	.1193	.....	.....
		Shaku	.....	.9943	.....
		Ri	.....	.....	2.4434
	Philippines,	Pulgada	.927	.....	.....
		Pie	.....	.927	.....
		Kilometro	.....	.....	.62138

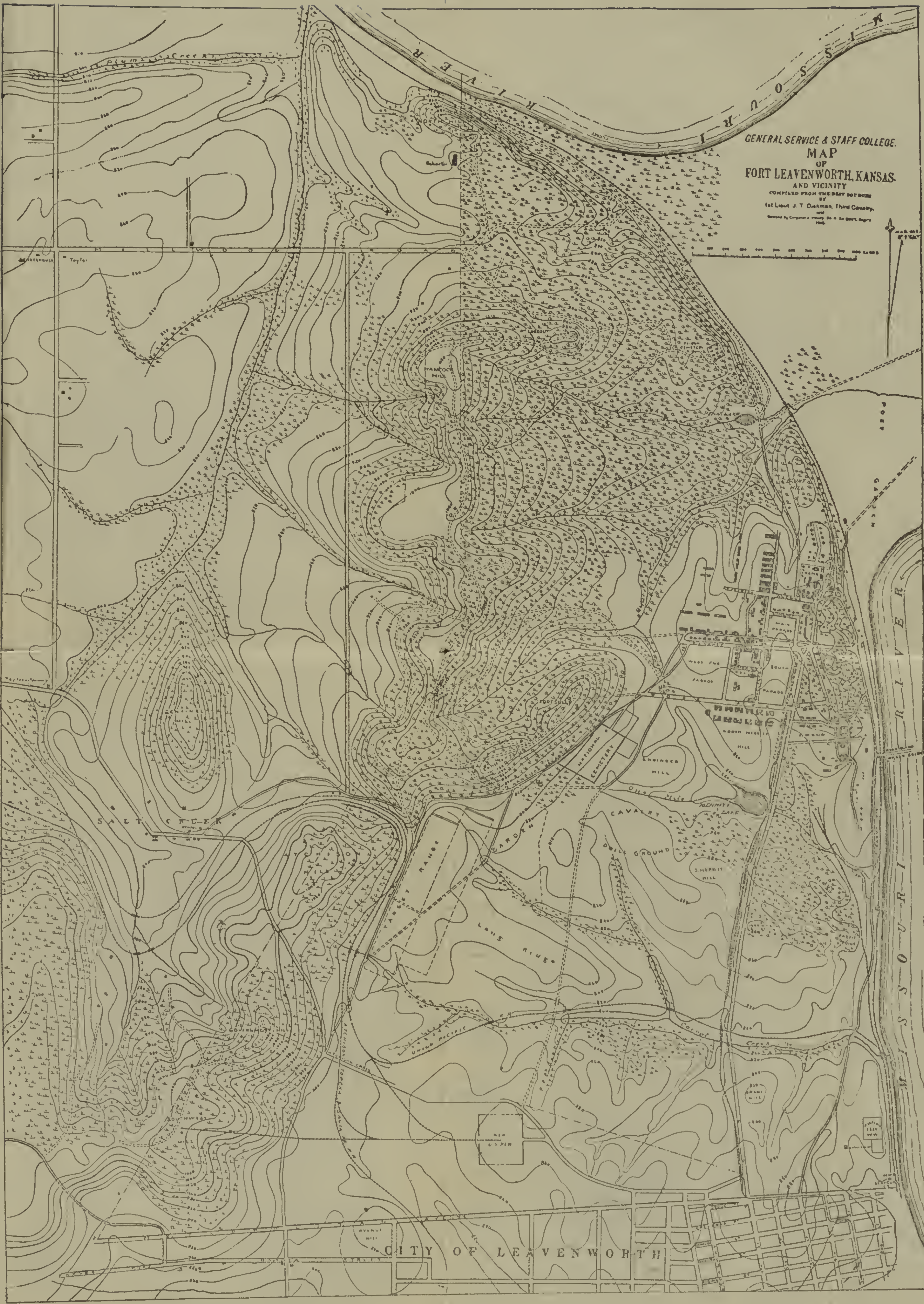
APPENDIX II—CONTINUED.

		Inches.	Feet.	Miles.
Prussia (old system),	Linie	.0859	.....	.....
	Fuss = 144 linien	.....	1.0297	.....
	Schritt (pace)	.....	2.4714	.....
	Meile = 24,000 fuss	.....	.....	4.6805
Russia,	Vershok	1.75	.....	.....
	English foot	....	1.00	.....
	Arschine = 16 vershoks	.....	2.3332	.....
	Sajène = 48 vershoks	.....	7.0000	.....
	Verst = 500 arschines	.....	.....	.6628
Sweden,	Linie	.11689	.....	.....
	Fot = 100 linier	.....	.9742	.....
	Meile = 36,000 fot	.....	.....	6.6416
Switzerland,	Linie	.11811	.....	.....
	Fuss = 100 linien	.....	.98427	.....
	Schweizerstunde = 16,000 fuss	.....	.....	2.9826
Turkey,	Kerat	1.125	.....	.....
	Halebi or archim	.....	2.325	.....
	Berri	.....	.....	1.0386


GENERAL SERVICE & STAFF COLLEGE.
MAP
OF
FORT LEAVENWORTH, KANSAS
AND VICINITY
1st Lieut. J. T. Dickman, Third Cavalry.
MISSOURI RIVER
HANCOCK HILL
SENTINEL HILL
SALT CREEK
NATIONAL CEMETERY
ENGINEER HILL
CAVALRY
DRILL GROUND
TARGET RANGE
GARDEN
Long Ridge
UNION PACIFIC
NEW U.S. PEN
CITY OF LEAVENWORTH

PLATE 20


MAP
OF
FORT LEAVENWORTH, KANSAS.
AND VICINITY
COMPILED FROM THE BEST SOURCES
BY
1st Lieut. J. T. Dickman, Third Cavalry.
MAG. VAR. 8° 7' EAST
YARDS
MISSOURI RIVER
Plum Creek
MILLWOOD ROAD
NORTH HILL
HANCOCK HILL
SENTINEL
SALT CREEK
FORT SULLY
NATIONAL CEMETERY
WEST END PARADE
MAIN PARADE
SOUTH PARADE
NORTH MERRITT HILL
MERRITT LAKE
CAVALRY DRILL GROUND
S. MERRITT HILL
TARGET RANGE
Long Ridge
GOVERNMENT HILL
SOUTHWEST HILL
UNION PACIFIC R.R.
ATCHISON TOPEKA & SANTA FE R.R.
Corral Creek
GRANT HILL
RABBIT POINT
NEW U.S. PEN.
AVENUE HILL
METROPOLITAN AVENUE
DAKOTA STREET
CITY OF LEAVENWORTH
A 860
4 770
H14
A14
B14
C14
F14
G14
B5
D14
E14
III/14
B 1080
H 1040
G 1020
I 1040
5 890
6 850
2 1045
3 1020
D 900
E 870
C 950
A



GENERAL SERVICE & STAFF COLLEGE.
MAP
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MISSOURI RIVER
MISSOURI RIVER
SALT CREEK
NATIONAL CEMETERY
ENGINEER HILL
CAVALRY
DRILL GROUND
TARGET RANGE
CITY OF LEAVENWORTH

SANDISFIELD SHEET

FOR

Practical Field Exercises

BY MAJOR JOHN P. WISSER, U. S. A.

HUDSON-KIMBERLY PUBLISHING CO.
KANSAS CITY, MO.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

SANDISFIELD SHEET

Scale $\frac{1}{62500}$

Contour interval 20 feet.

Datum is mean sea level.

Miles

Kilometers